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(54) Title: INVASIVE CLEAVAGE OF NUCLEIC ACIDS			
(57) Abstract <p>The present invention relates to means for the detection and characterization of nucleic acid sequences, as well as variations in nucleic acid sequences. The present invention also relates to methods for forming a nucleic acid cleavage structure on a target sequence and cleaving the nucleic acid cleavage structure in a site-specific manner. The structure-specific nuclease activity of a variety of enzymes is used to cleave the target-dependent cleavage structure, thereby indicating the presence of specific nucleic acid sequences or specific variations thereof. The present invention further relates to methods and devices for the separation of nucleic acid molecules based on charge. The present invention also provides methods for the detection of non-target cleavage products via the formation of a complete and activated protein binding region.</p>			

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INVASIVE CLEAVAGE OF NUCLEIC ACIDS

FIELD OF THE INVENTION

The present invention relates to means for the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. The present invention relates to methods for forming a nucleic acid cleavage structure on a target sequence and cleaving the nucleic acid cleavage structure in a site-specific manner. The 5' nuclease activity of a variety of enzymes is used to cleave the target-dependent cleavage structure, thereby indicating the presence of specific nucleic acid sequences or specific variations thereof. The present invention further provides novel methods and devices for the separation of nucleic acid molecules based by charge. The present invention further provides methods for the detection of non-target cleavage products via the formation of a complete and activated protein binding region.

BACKGROUND OF THE INVENTION

The detection and characterization of specific nucleic acid sequences and sequence variations has been utilized to detect the presence of viral or bacterial nucleic acid sequences indicative of an infection, the presence of variants or alleles of mammalian genes associated with disease and cancers and the identification of the source of nucleic acids found in forensic samples, as well as in paternity determinations.

Various methods are known to the art which may be used to detect and characterize specific nucleic acid sequences and sequence variants. Nonetheless, as nucleic acid sequence data of the human genome, as well as the genomes of pathogenic organisms accumulates, the demand for fast, reliable, cost-effective and user-friendly tests for the detection of specific nucleic acid sequences continues to grow. Importantly, these tests must be able to create a detectable signal from samples which contain very few copies of the sequence of interest. The following discussion examines two levels of nucleic acid detection assays currently in use: I. Signal Amplification Technology for detection of rare sequences; and II. Direct Detection Technology for quantitative detection of sequences.

I. Signal Amplification Technology Methods For Amplification

The "Polymerase Chain Reaction" (PCR) comprises the first generation of methods for nucleic acid amplification. However, several other methods have been developed that employ

the same basis of specificity, but create signal by different amplification mechanisms. These methods include the "Ligase Chain Reaction" (LCR), "Self-Sustained Synthetic Reaction" (3SR/NASBA), and "Q β -Replicase" (Q β).

5 **Polymerase Chain Reaction (PCR)**

The polymerase chain reaction (PCR), as described in U.S. Patent Nos. 4,683,195 and 4,683,202 to Mullis and Mullis *et al.* (the disclosures of which are hereby incorporated by reference), describe a method for increasing the concentration of a segment of target sequence in a mixture of genomic DNA without cloning or purification. This technology provides one
10 approach to the problems of low target sequence concentration. PCR can be used to directly increase the concentration of the target to an easily detectable level. This process for amplifying the target sequence involves introducing a molar excess of two oligonucleotide primers which are complementary to their respective strands of the double-stranded target sequence to the DNA mixture containing the desired target sequence. The mixture is
15 denatured and then allowed to hybridize. Following hybridization, the primers are extended with polymerase so as to form complementary strands. The steps of denaturation, hybridization, and polymerase extension can be repeated as often as needed, in order to obtain relatively high concentrations of a segment of the desired target sequence.

The length of the segment of the desired target sequence is determined by the relative
20 positions of the primers with respect to each other, and, therefore, this length is a controllable parameter. Because the desired segments of the target sequence become the dominant sequences (in terms of concentration) in the mixture, they are said to be "PCR-amplified."

Ligase Chain Reaction (LCR or LAR)

25 The ligase chain reaction (LCR; sometimes referred to as "Ligase Amplification Reaction" (LAR) described by Barany, Proc. Natl. Acad. Sci., 88:189 (1991); Barany, PCR Methods and Applic., 1:5 (1991); and Wu and Wallace, Genomics 4:560 (1989) has developed into a well-recognized alternative method for amplifying nucleic acids. In LCR, four oligonucleotides, two adjacent oligonucleotides which uniquely hybridize to one strand of
30 target DNA, and a complementary set of adjacent oligonucleotides, which hybridize to the opposite strand are mixed and DNA ligase is added to the mixture. Provided that there is complete complementarity at the junction, ligase will covalently link each set of hybridized molecules. Importantly, in LCR, two probes are ligated together only when they base-pair

with sequences in the target sample, without gaps or mismatches. Repeated cycles of denaturation, hybridization and ligation amplify a short segment of DNA. LCR has also been used in combination with PCR to achieve enhanced detection of single-base changes. Segev, PCT Public. No. W09001069 A1 (1990). However, because the four oligonucleotides used in this assay can pair to form two short ligatable fragments, there is the potential for the generation of target-independent background signal. The use of LCR for mutant screening is limited to the examination of specific nucleic acid positions.

Self-Sustained Synthetic Reaction (3SR/NASBA)

The self-sustained sequence replication reaction (3SR) (Guatelli *et al.*, Proc. Natl. Acad. Sci., 87:1874-1878 [1990], with an erratum at Proc. Natl. Acad. Sci., 87:7797 [1990]) is a transcription-based *in vitro* amplification system (Kwok *et al.*, Proc. Natl. Acad. Sci., 86:1173-1177 [1989]) that can exponentially amplify RNA sequences at a uniform temperature. The amplified RNA can then be utilized for mutation detection (Fahy *et al.*, PCR Meth. Appl., 1:25-33 [1991]). In this method, an oligonucleotide primer is used to add a phage RNA polymerase promoter to the 5' end of the sequence of interest. In a cocktail of enzymes and substrates that includes a second primer, reverse transcriptase, RNase H, RNA polymerase and ribo- and deoxyribonucleoside triphosphates, the target sequence undergoes repeated rounds of transcription, cDNA synthesis and second-strand synthesis to amplify the area of interest. The use of 3SR to detect mutations is kinetically limited to screening small segments of DNA (*e.g.*, 200-300 base pairs).

Q-Beta (Q β) Replicase

In this method, a probe which recognizes the sequence of interest is attached to the replicatable RNA template for Q β replicase. A previously identified major problem with false positives resulting from the replication of unhybridized probes has been addressed through use of a sequence-specific ligation step. However, available thermostable DNA ligases are not effective on this RNA substrate, so the ligation must be performed by T4 DNA ligase at low temperatures (37°C). This prevents the use of high temperature as a means of achieving specificity as in the LCR, the ligation event can be used to detect a mutation at the junction site, but not elsewhere.

Table 1 below, lists some of the features desirable for systems useful in sensitive nucleic acid diagnostics, and summarizes the abilities of each of the major amplification methods (*See also*, Landgren, Trends in Genetics 9:199 [1993]).

A successful diagnostic method must be very specific. A straight-forward method of controlling the specificity of nucleic acid hybridization is by controlling the temperature of the reaction. While the 3SR/NASBA, and Q β systems are all able to generate a large quantity of signal, one or more of the enzymes involved in each cannot be used at high temperature (*i.e.*, >55°C). Therefore the reaction temperatures cannot be raised to prevent non-specific hybridization of the probes. If probes are shortened in order to make them melt more easily at low temperatures, the likelihood of having more than one perfect match in a complex genome increases. For these reasons, PCR and LCR currently dominate the research field in detection technologies.

TABLE 1

Feature	Method				
	PCR	LCR	PCR & LCR	3SR NASBA	Q β
Amplifies Target	+	+	+	+	
Recognition of Independent Sequences Required	+	+	+	+	+
Performed at High Temp.	+	+			
Operates at Fixed Temp.				+	+
Exponential Amplification	+	+	+	+	+
Generic Signal Generation					+
Easily Automatable					

The basis of the amplification procedure in the PCR and LCR is the fact that the products of one cycle become usable templates in all subsequent cycles, consequently doubling the population with each cycle. The final yield of any such doubling system can be expressed as: $(1+X)^n = y$, where "X" is the mean efficiency (percent copied in each cycle), "n" is the number of cycles, and "y" is the overall efficiency, or yield of the reaction (Mullis, PCR Methods Applic., 1:1 [1991]). If every copy of a target DNA is utilized as a template in every cycle of a polymerase chain reaction, then the mean efficiency is 100%. If 20 cycles of PCR are performed, then the yield will be 2^{20} , or 1,048,576 copies of the starting material. If the reaction conditions reduce the mean efficiency to 85%, then the yield in those 20 cycles

will be only 1.85^{20} , or 220.513 copies of the starting material. In other words, a PCR running at 85% efficiency will yield only 21% as much final product, compared to a reaction running at 100% efficiency. A reaction that is reduced to 50% mean efficiency will yield less than 1% of the possible product.

5 In practice, routine polymerase chain reactions rarely achieve the theoretical maximum yield, and PCRs are usually run for more than 20 cycles to compensate for the lower yield. At 50% mean efficiency, it would take 34 cycles to achieve the million-fold amplification theoretically possible in 20, and at lower efficiencies, the number of cycles required becomes prohibitive. In addition, any background products that amplify with a better mean efficiency
10 than the intended target will become the dominant products.

Also, many variables can influence the mean efficiency of PCR, including target DNA length and secondary structure, primer length and design, primer and dNTP concentrations, and buffer composition, to name but a few. Contamination of the reaction with exogenous DNA (e.g., DNA spilled onto lab surfaces) or cross-contamination is also a major
15 consideration. Reaction conditions must be carefully optimized for each different primer pair and target sequence, and the process can take days, even for an experienced investigator. The laboriousness of this process, including numerous technical considerations and other factors, presents a significant drawback to using PCR in the clinical setting. Indeed, PCR has yet to penetrate the clinical market in a significant way. The same concerns arise with LCR, as
20 LCR must also be optimized to use different oligonucleotide sequences for each target sequence. In addition, both methods require expensive equipment, capable of precise temperature cycling.

Many applications of nucleic acid detection technologies, such as in studies of allelic variation, involve not only detection of a specific sequence in a complex background, but also
25 the discrimination between sequences with few, or single, nucleotide differences. One method for the detection of allele-specific variants by PCR is based upon the fact that it is difficult for *Taq* polymerase to synthesize a DNA strand when there is a mismatch between the template strand and the 3' end of the primer. An allele-specific variant may be detected by the use of a primer that is perfectly matched with only one of the possible alleles; the
30 mismatch to the other allele acts to prevent the extension of the primer, thereby preventing the amplification of that sequence. This method has a substantial limitation in that the base composition of the mismatch influences the ability to prevent extension across the mismatch.

and certain mismatches do not prevent extension or have only a minimal effect (Kwok *et al.*, Nucl. Acids Res., 18:999 [1990]).

A similar 3'-mismatch strategy is used with greater effect to prevent ligation in the LCR (Barany, PCR Meth. Applic., 1:5 [1991]). Any mismatch effectively blocks the action of the thermostable ligase, but LCR still has the drawback of target-independent background ligation products initiating the amplification. Moreover, the combination of PCR with subsequent LCR to identify the nucleotides at individual positions is also a clearly cumbersome proposition for the clinical laboratory.

10 II. Direct Detection Technology

When a sufficient amount of a nucleic acid to be detected is available, there are advantages to detecting that sequence directly, instead of making more copies of that target. (e.g., as in PCR and LCR). Most notably, a method that does not amplify the signal exponentially is more amenable to quantitative analysis. Even if the signal is enhanced by attaching multiple dyes to a single oligonucleotide, the correlation between the final signal intensity and amount of target is direct. Such a system has an additional advantage that the products of the reaction will not themselves promote further reaction, so contamination of lab surfaces by the products is not as much of a concern. Traditional methods of direct detection including Northern and Southern blotting and RNase protection assays usually require the use of radioactivity and are not amenable to automation. Recently devised techniques have sought to eliminate the use of radioactivity and/or improve the sensitivity in automatable formats. Two examples are the "Cycling Probe Reaction" (CPR), and "Branched DNA" (bDNA)

The cycling probe reaction (CPR) (Duck *et al.*, BioTech., 9:142 [1990]), uses a long chimeric oligonucleotide in which a central portion is made of RNA while the two termini are made of DNA. Hybridization of the probe to a target DNA and exposure to a thermostable RNase H causes the RNA portion to be digested. This destabilizes the remaining DNA portions of the duplex, releasing the remainder of the probe from the target DNA and allowing another probe molecule to repeat the process. The signal, in the form of cleaved probe molecules, accumulates at a linear rate. While the repeating process increases the signal, the RNA portion of the oligonucleotide is vulnerable to RNases that may be carried through sample preparation.

Branched DNA (bDNA), described by Urdea *et al.*, Gene 61:253-264 (1987), involves oligonucleotides with branched structures that allow each individual oligonucleotide to carry

35 to 40 labels (*e.g.*, alkaline phosphatase enzymes). While this enhances the signal from a hybridization event, signal from non-specific binding is similarly increased.

While both of these methods have the advantages of direct detection discussed above, neither the CPR or bDNA methods can make use of the specificity allowed by the requirement of independent recognition by two or more probe (oligonucleotide) sequences, as is common in the signal amplification methods described in section I. above. The requirement that two oligonucleotides must hybridize to a target nucleic acid in order for a detectable signal to be generated confers an extra measure of stringency on any detection assay. Requiring two oligonucleotides to bind to a target nucleic acid reduces the chance that false "positive" results will be produced due to the non-specific binding of a probe to the target. The further requirement that the two oligonucleotides must bind in a specific orientation relative to the target, as is required in PCR, where oligonucleotides must be oppositely but appropriately oriented such that the DNA polymerase can bridge the gap between the two oligonucleotides in both directions, further enhances specificity of the detection reaction. However, it is well known to those in the art that even though PCR utilizes two oligonucleotide probes (termed primers) "non-specific" amplification (*i.e.*, amplification of sequences not directed by the two primers used) is a common artifact. This is in part because the DNA polymerase used in PCR can accommodate very large distances, measured in nucleotides, between the oligonucleotides and thus there is a large window in which non-specific binding of an oligonucleotide can lead to exponential amplification of inappropriate product. The LCR, in contrast, cannot proceed unless the oligonucleotides used are bound to the target adjacent to each other and so the full benefit of the dual oligonucleotide hybridization is realized.

An ideal direct detection method would combine the advantages of the direct detection assays (*e.g.*, easy quantification and minimal risk of carry-over contamination) with the specificity provided by a dual oligonucleotide hybridization assay.

SUMMARY OF THE INVENTION

The present invention relates to means for cleaving a nucleic acid cleavage structure in a site-specific manner. In a preferred embodiment, the means for cleaving is a structure-specific nuclease. Particularly preferred structure-specific nucleases are thermostable structure-specific nucleases. In one embodiment, the structure-specific nuclease is an enzyme comprising 5' nucleases derived from thermostable DNA polymerases. These polymerases

form the basis of a novel method of detection of specific nucleic acid sequences. The present invention contemplates use of novel detection methods for various uses, including, but not limited to clinical diagnostic purposes.

In one embodiment, the present invention contemplates a DNA sequence encoding a DNA polymerase altered in sequence (*i.e.*, a "mutant" DNA polymerase) relative to the native sequence, such that it exhibits altered DNA synthetic activity from that of the native (*i.e.*, "wild type") DNA polymerase. It is preferred that the encoded DNA polymerase is altered such that it exhibits reduced synthetic activity compared to that of the native DNA polymerase. In this manner, the enzymes of the invention are predominantly 5' nucleases and are capable of cleaving nucleic acids in a structure-specific manner in the absence of interfering synthetic activity.

Importantly, the 5' nucleases of the present invention are capable of cleaving linear duplex structures to create single discrete cleavage products. These linear structures are either 1) not cleaved by the wild type enzymes (to any significant degree), or 2) are cleaved by the wild type enzymes so as to create multiple products. This characteristic of the 5' nucleases has been found to be a consistent property of enzymes derived in this manner from thermostable polymerases across eubacterial thermophilic species.

It is not intended that the invention be limited by the nature of the alteration necessary to render the polymerase synthesis-deficient. Nor is it intended that the invention be limited by the extent of the deficiency. The present invention contemplates various structures, including altered structures (primary, secondary, etc.), as well as native structures, that may be inhibited by synthesis inhibitors.

Where the polymerase structure is altered, it is not intended that the invention be limited by the means by which the structure is altered. In one embodiment, the alteration of the native DNA sequence comprises a change in a single nucleotide. In another embodiment, the alteration of the native DNA sequence comprises a deletion of one or more nucleotides. In yet another embodiment, the alteration of the native DNA sequence comprises an insertion of one or more nucleotides. It is contemplated that the change in DNA sequence may manifest itself as change in amino acid sequence.

The present invention contemplates structure-specific nucleases from a variety of sources, including mesophilic, psychrophilic, thermophilic, and hyperthermophilic organisms. The preferred structure-specific nucleases are thermostable. Thermostable structure-specific nucleases are contemplated as particularly useful in that they operate at temperatures where

nucleic acid hybridization is extremely specific, allowing for allele-specific detection (including single-base mismatches). In one embodiment, the thermostable structure-specific are thermostable 5' nucleases which are selected from the group consisting of altered polymerases derived from the native polymerases of *Thermus* species, including, but not limited to *Thermus aquaticus*, *Thermus flavus*, and *Thermus thermophilus*. However, the invention is not limited to the use of thermostable 5' nucleases. Thermostable structure-specific nucleases from the FEN-1, RAD2 and XPG class of nucleases are also preferred.

Accordingly, the present invention provides improved enzymatic cleavage means. In one embodiment, the present invention provides a thermostable structure-specific nuclease having an amino acid sequence selected from the group consisting of SEQ ID NOS:61, 66, 69 and 72. In another embodiment, the nuclease is encoded by a DNA sequence selected from the group consisting of SEQ ID NO:60, 65, 68 and 70.

The present invention also provides a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a structure-specific nuclease, the nucleotide sequence selected from the group consisting of SEQ ID NO:60, 65, 68 and 70. In a preferred embodiment, the invention provides a host cell transformed with a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a structure-specific nuclease, the nucleotide sequence selected from the group consisting of SEQ ID NO:60, 65, 68 and 70. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of nucleotide sequences encoding structure-specific nucleases which can be expressed in a variety of procaryotic and eucaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

The present invention provides a purified *Pyrococcus woesei* FEN-1 endonuclease. In a preferred embodiment, the purified *Pyrococcus woesei* FEN-1 endonuclease has a molecular weight of about 38.7 kilodaltons (the molecular weight may be conveniently estimated using SDS-PAGE as described in Ex. 28).

The present invention further provides an isolated oligonucleotide encoding a *Pyrococcus woesei* FEN-1 endonuclease, the oligonucleotide having a region capable of hybridizing an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:80-83. In a preferred embodiment, the oligonucleotide encoding the purified *Pyrococcus woesei* FEN-1 endonuclease is operably linked to a heterologous promoter. The present invention is not limited by the nature of the heterologous promoter employed; in a preferred embodiment, the heterologous promoter is an inducible promoter (the promoter chosen will

depend upon the host cell chosen for expression as is known in the art). The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoter include the λ -P_L promoter, the *tac* promoter, the *trp* promoter and the *trc* promoter.

5 In another preferred embodiment, the invention provides a recombinant DNA vector comprising an isolated oligonucleotide encoding a *Pyrococcus wosei* (*Pwo*) FEN-1 endonuclease, the oligonucleotide having a region capable of hybridizing to an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:80-83. Host cells transformed with these recombinant vectors are also provided. In a preferred embodiment, the invention provides a host cell transformed with a recombinant DNA vector comprising DNA having a
10 region capable of hybridizing to an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:80-83; these vectors may further comprise a heterologous promoter operably linked to the *Pwo* FEN-1-encoding polynucleotides. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of *Pwo* FEN-1-encoding polynucleotides which can be expressed in a variety of
15 procaryotic and eucaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

In yet another embodiment, the invention provides an isolated oligonucleotide comprising a gene encoding a *Pyrococcus wosei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons. In another embodiment, the encoding a *Pyrococcus wosei*
20 FEN-1 endonuclease is operably linked to a heterologous promoter. The present invention is not limited by the nature of the heterologous promoter employed; in a preferred embodiment, the heterologous promoter is an inducible promoter (the promoter chosen will depend upon the host cell chosen for expression as is known in the art). The invention is not limited by the nature of the inducible promoter employed. Preferred inducible promoter include the λ -P_L
25 promoter, the *tac* promoter, the *trp* promoter and the *trc* promoter.

The invention further provides a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a *Pyrococcus woessii* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons. Still further, a host cell transformed with a recombinant DNA vector comprising DNA having a nucleotide sequence encoding a *Pyrococcus woessii*
30 FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons is provided. The invention is not limited by the nature of the host cell employed. The art is well aware of expression vectors suitable for the expression of *Pwo* FEN-1-encoding polynucleotides which

can be expressed in a variety of procaryotic and eucaryotic host cells. In a preferred embodiment, the host cell is an *Escherichia coli* cell.

As noted above, the present invention contemplates the use of structure-specific nucleases in a detection method. In one embodiment, the present invention provides a method
5 of detecting the presence of a target nucleic acid by detecting non-target cleavage products comprising: a) providing: i) a cleavage means, ii) a source of target nucleic acid, where the target nucleic acid has a first region, a second region and a third region, wherein the first region is located adjacent to and downstream from the second region, and the second region is located adjacent to and downstream from the third region, iii) a first oligonucleotide having a
10 5' and a 3' portion, wherein the 5' portion of the first oligonucleotide contains a sequence complementary to the second region of the target nucleic acid and wherein the 3' portion of the first oligonucleotide contains a sequence complementary to the third region of the target nucleic acid, iv) a second oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the first region of the
15 target nucleic acid, and the 3' portion of the second oligonucleotide contains a sequence complementary to the second region of the target nucleic acid; b) mixing the cleavage means, target nucleic acid, and the first and second oligonucleotides, to create a reaction mixture under reaction conditions such that at least the 3' portion of the first oligonucleotide is annealed to the target nucleic acid, and wherein at least the 5' portion of the second
20 oligonucleotide is annealed to the target nucleic acid so as to create a cleavage structure, and wherein cleavage of the cleavage structure occurs to generate non-target cleavage products; and c) detecting the non-target cleavage products.

It is contemplated that the first, second and third regions of the target be located adjacent to each other. However, the invention is not limited to the use of a target in which
25 the three regions are contiguous with each other. Thus, the present invention contemplates the use of target nucleic acids wherein these three regions are contiguous with each other, as well as target acids wherein these three regions are not contiguous. It is further contemplated that gaps of approximately 2-10 nucleotides, representing regions of non-complementarity to the oligonucleotides (e.g., the first and/or second oligonucleotides), may be present between
30 the three regions of the target nucleic acid.

In at least one embodiment, it is intended that mixing of step b) is conducted under conditions such that at least the 3' portion of the first oligonucleotide is annealed to the target nucleic acid, and wherein at least the 5' portion of the second oligonucleotide is annealed to

the target nucleic acid. In this manner a cleavage structure is created and cleavage of this cleavage structure can occur. These conditions allow for the use of various formats. In a preferred format, the conditions of mixing comprises mixing together the target nucleic acid with the first and second oligonucleotides and the cleavage means in an aqueous solution in which a source of divalent cations is lacking. In this format, the cleavage reaction is initiated by the addition of a solution containing Mn^{2+} or Mg^{2+} ions. In another preferred format, the conditions of mixing comprises mixing together the target nucleic acid, and the first and second oligonucleotides in an aqueous solution containing Mn^{2+} or Mg^{2+} ions, and then adding the cleavage means to the reaction mixture.

It is contemplated that the oligonucleotides may be labelled. Thus, if the cleavage reaction employs a first oligonucleotide containing a label, detection of the non-target cleavage products may comprise detection of the label. The invention is not limited by the nature of the label chosen, including, but not limited to, labels which comprise a dye or a radionucleotide (e.g., ^{32}P), fluorescein moiety, a biotin moiety, luminogenic, fluorogenic, phosphorescent, or fluors in combination with moieties that can suppress emission by fluorescence energy transfer (FET). Numerous methods are available for the detection of nucleic acids containing any of the above-listed labels. For example, biotin-labeled oligonucleotide(s) may be detected using non-isotopic detection methods which employ streptavidin-alkaline phosphatase conjugates. Fluorescein-labelled oligonucleotide(s) may be detected using a fluorescein-imager.

It is also contemplated that labelled oligonucleotides (cleaved or uncleaved) may be separated by means other than electrophoresis. For example, biotin-labelled oligonucleotides may be separated from nucleic acid present in the reaction mixture using para-magnetic or magnetic beads, or particles which are coated with avidin (or streptavidin). In this manner, the biotinylated oligonucleotide/avidin-magnetic bead complex can be physically separated from the other components in the mixture by exposing the complexes to a magnetic field. Additionally, the signal from the cleaved oligonucleotides may be resolved from that of the uncleaved oligonucleotides without physical separation. For example, a change in size, and therefore rate of rotation in solution of fluorescent molecules can be detected by fluorescence polarization analysis.

In a preferred embodiment, the reaction conditions comprise a cleavage reaction temperature which is less than the melting temperature of the first oligonucleotide and greater than the melting temperature of the 3' portion of the first oligonucleotide. In a particularly

preferred embodiment, the reaction temperature is between approximately 40-75°C. It is contemplated that the reaction temperature at which the cleavage reaction occurs be selected with regard to the guidelines provided in the Description of the Invention.

5 The method of the present invention is not limited by the nature of the target nucleic acid. The target nucleic acid may comprise single-stranded or double-stranded DNA, RNA, and/or DNA/RNA hybrids. When a double-stranded target nucleic acid is employed, the reaction mixture may be treated such that the aid double-stranded DNA is rendered substantially single-stranded. A preferred method for rendering double-stranded DNA substantially single-stranded is by the use of increased temperature. When target nucleic acids
10 comprising RNA are employed, the oligonucleotides may comprise DNA, RNA or an oligonucleotide comprising a mixture of RNA and DNA. It is not intended that the invention be limited by the nature of the oligonucleotides employed.

The oligonucleotides may comprise DNA, RNA or an oligonucleotide comprising a mixture of RNA and DNA. The invention also contemplates the use of a second
15 oligonucleotide (*i.e.*, the upstream oligonucleotide) which comprises a functional group (*e.g.*, a 5' peptide region) which prevents the dissociation of the 5' portion of the second oligonucleotide from the first region of the target nucleic acid. When such a functional group is present on the second oligonucleotide, the interaction between the 3' portion of the second oligonucleotide and the first region of the target nucleic acid may be destabilized (*i.e.*,
20 designed to have a lower local melting temperature) through the use of A-T rich sequences, base analogs that form fewer hydrogen bonds (*e.g.*, dG-dU pairs) or through the use of phosphorothioate backbones, in order to allow the 5' region of the first oligonucleotide to compete successfully for hybridization.

The invention is not limited to use of oligonucleotides which are completely
25 complementary to their cognate target sequences. In one embodiment, both the first and second oligonucleotides are completely complementary to the target nucleic acid. In another embodiment, the first oligonucleotide is partially complementary to the target nucleic acid. In yet another embodiment, the second oligonucleotide is partially complementary to the target nucleic acid. In yet another embodiment, both the first and the second oligonucleotide are
30 partially complementary to the target nucleic acid.

The methods of the invention may employ a source of target nucleic acid which comprises a sample containing genomic DNA. In a preferred embodiment, the sample

containing genomic DNA is selected from the group including, but not limited to blood, saliva, cerebral spinal fluid, pleural fluid, milk, lymph, sputum and semen.

In a preferred embodiment, the method employs reaction conditions which comprise providing a source of divalent cations. In a particularly preferred embodiment, the divalent cation is selected from the group comprising Mn^{2+} and Mg^{2+} ions.

The invention also provides a method for detecting the presence of a target nucleic acid in a sample by generating non-target cleavage products, comprising: a) providing: i) a cleavage means; ii) a sample suspected of containing a target nucleic acid having a first region, a second region and a third region, wherein the first region is located adjacent to and downstream from the second region and wherein the second region is located adjacent to and downstream from the third region; iii) a first oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the first oligonucleotide contains a sequence complementary to the second region of the target nucleic acid and wherein the 3' portion of the first oligonucleotide contains a sequence complementary to the third region of the target nucleic acid; iv) a second oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the first region of the target nucleic acid, and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the second region of the target nucleic acid; b) mixing the cleavage means and the first and second oligonucleotides to create a reaction mixture under reaction conditions, wherein the target nucleic acid and the first and second oligonucleotides form one or more cleavage structures and wherein the cleavage means cleaves the cleavage structures, resulting in the cleavage of the first oligonucleotide; and c) distinguishing the cleaved first oligonucleotide from the uncleaved first oligonucleotide, the second oligonucleotide and the target nucleic acid. In a preferred embodiment, the cleaved first oligonucleotide is distinguished from the uncleaved first oligonucleotide, second oligonucleotide and target nucleic acid by electrophoresis of the reaction mixture after cleavage has occurred, to separate the cleaved first oligonucleotide from the uncleaved first oligonucleotide, second oligonucleotide and target nucleic acid, followed by visualization of the separated cleaved first oligonucleotide. As noted above, the invention is not limited to the use of the physical separation of the reaction products for the distinguishing of the cleaved first oligonucleotide.

In a preferred embodiment, the first oligonucleotide contains a fluorescent label and visualization of the separated cleaved first oligonucleotide consists of detecting the label through use of a fluorescence imager.

In a particularly preferred embodiment, the first oligonucleotide is present in excess relative to the target nucleic acid. In one embodiment, the first oligonucleotide is preferably present in about at least a 100-fold molar excess relative to the target nucleic acid.

5 The invention further contemplates a method wherein the first oligonucleotide is present in excess relative to the target nucleic acid, and the amount of cleaved first oligonucleotide produced in the cleavage reaction is measured, such that the amount of the target nucleic acid present in the sample can be determined.

10 In a preferred embodiment, the conditions of step b) comprise the use of a cleavage reaction temperature which is less than the melting temperature of the first oligonucleotide and greater than the melting temperature of the 3' portion of the first oligonucleotide.

As discussed above, the invention contemplates that the cleavage means comprises a thermostable 5' nuclease, although the invention is not limited to the use of a thermostable 5' nuclease. When a thermostable 5' nuclease is employed, a portion of the amino acid sequence of the nuclease may be homologous to a portion of the amino acid sequence of a thermostable DNA polymerase derived from a thermophilic organism.

15 The present invention further provides a method of detecting sequence variation in a plurality of nucleic acid target sequences wherein the target nucleic acid sequences differ in sequence, comprising the steps of: a) providing: i) a cleavage means; ii) a sample suspected of containing a first target nucleic acid and a second target nucleic acid, wherein the first and second target nucleic acids have a first region, a second region and a third region, and wherein the first region is located adjacent to and downstream from the second region, the second region is located adjacent to and downstream from the third region, and the sequence of said first and second target nucleic acids differ from one another by at least one nucleotide within their respective third regions; iii) a first oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the first oligonucleotide contains a sequence complementary to the second region of the first and second target nucleic acids, and wherein the 3' portion of the first oligonucleotide contains a sequence complementary to the third region of the first target nucleic acid; iv) a second oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the second region of the first and second target nucleic acids, and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the third region of the second target nucleic acid; v) a third oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the third oligonucleotide contains a sequence complementary to the first region of the first and second

target nucleic acids, and wherein the 3' portion of the third oligonucleotide contains a sequence complementary to the first and second region of the target nucleic acids; b) mixing the cleavage means, the first and second target nucleic acids, and the first, second, and third oligonucleotides, to create a reaction mixture under reaction conditions such that the first and second target nucleic acids, and the first, second, and third oligonucleotides form one or more cleavage structures, and the cleavage means cleaves the cleavage structures, resulting in the cleavage of one or more of the first and second oligonucleotides; c) distinguishing the cleaved first and second oligonucleotides from the uncleaved first and second oligonucleotides, the third oligonucleotide, and the first and second target nucleic acids.

The invention is not limited to the use of two or more target nucleic acids that differ from one another by at least one nucleotide within their respective third regions. Target nucleic acid molecules which differ from one another by at least one nucleotide within their respective second regions may also be employed. In this embodiment, suitably designed first, second, and third oligonucleotides are employed.

In a preferred embodiment of the method which employs target nucleic acids which differ from one another by at least one nucleotide within their respective third regions, the first oligonucleotide contains a first label and the second oligonucleotide contains a second label.

In yet another preferred embodiment, the distinguishing of step c) comprises separation of the cleaved first oligonucleotide from the uncleaved first oligonucleotide, second oligonucleotide and target nucleic acid, and further comprising the step d) of detecting the separated cleaved and uncleaved products to permit a determination of the presence and relative abundance of the first and second target nucleic acids in the sample.

In still another preferred embodiment, the conditions of step b) comprise the use of a cleavage reaction temperature which is less than the melting temperature of the first and second oligonucleotides, and greater than the melting temperature of the 3' portion of the first oligonucleotide and the 3' portion of the second oligonucleotide. As discussed above, the methods of the invention preferably employ thermostable 5' nucleases as the cleavage means, although the invention is not limited to the use of thermostable 5' nucleases.

The novel detection methods of the invention may be employed for the detection of target nucleic acids including, but not limited to, target nucleic acids comprising wild type and mutant alleles of genes, including genes from humans or other animals that are or may be associated with disease or cancer. In addition, the methods of the invention may be used for

the detection of and/or identification of strains of microorganisms, including bacteria, fungi, protozoa, ciliates and viruses.

In one embodiment, the present invention provides a method of detecting the presence of a target RNA by detecting non-target cleavage products comprising: a) providing: i) a
5 cleavage means, ii) a source of target RNA, where the target RNA has a first region, a second region and a third region, wherein the first region is located adjacent to and downstream from the second region, and the second region is located adjacent to and downstream from the third region, iii) a first oligonucleotide having a 5' and a 3' portion, wherein the 5' portion of the first oligonucleotide contains a sequence complementary to the second region of the target
10 RNA and wherein the 3' portion of the first oligonucleotide contains a sequence complementary to the third region of the target RNA, iv) a second oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the second oligonucleotide contains a sequence complementary to the first region of the target RNA, and the 3' portion of the second oligonucleotide contains a sequence complementary to the second region of the target RNA;
15 b) mixing the cleavage means, the target RNA, and the first and second oligonucleotides, to create a reaction mixture under reaction conditions such that at least the 3' portion of the first oligonucleotide is annealed to the target RNA, and wherein at least the 5' portion of the second oligonucleotide is annealed to the target RNA so as to create a cleavage structure, and wherein cleavage of the cleavage structure occurs to generate non-target cleavage products;
20 and c) detecting the non-target cleavage products.

It is contemplated that the first, second and third regions of the target be located adjacent to each other. However, the invention is not limited to the use of a target in which the three regions are contiguous with each other. Thus, the present invention contemplates the use of target RNAs wherein these three regions are contiguous with each other, as well as
25 target RNAs wherein these three regions are not contiguous. It is further contemplated that gaps of approximately 2-10 nucleotides, representing regions of non-complementarity to the oligonucleotides (e.g., the first and/or second oligonucleotides), may be present between the three regions of the target RNA.

In at least one embodiment, it is intended that mixing of step b) is conducted under
30 conditions such that at least the 3' portion of the first oligonucleotide is annealed to the target RNA, and wherein at least the 5' portion of the second oligonucleotide is annealed to the target RNA. In this manner a cleavage structure is created and cleavage of this cleavage structure can occur. These conditions allow for the use of various formats. In a preferred

format. the conditions of mixing comprises mixing together the target RNA with the first and second oligonucleotides and the cleavage means in an aqueous solution in which a source of divalent cations is lacking. In this format, the cleavage reaction is initiated by the addition of a solution containing Mn^{2+} or Mg^{2+} ions. In another preferred format, the conditions of mixing comprises mixing together the target RNA, and the first and second oligonucleotides in an aqueous solution containing Mn^{2+} or Mg^{2+} ions, and then adding the cleavage means to the reaction mixture.

The invention is not limited by the means employed for the detection of the non-target cleavage products. For example, the products generated by the cleavage reaction (*i.e.*, the non-target cleavage products) may be detected by their separation of the reaction products on agarose or polyacrylamide gels and staining with ethidium bromide. Other non-gel-based detection methods are provided herein.

It is contemplated that the oligonucleotides may be labelled. Thus, if the cleavage reaction employs a first oligonucleotide containing a label, detection of the non-target cleavage products may comprise detection of the label. The invention is not limited by the nature of the label chosen, including, but not limited to, labels which comprise a dye or a radionucleotide (*e.g.*, ^{32}P), fluorescein moiety, a biotin moiety, luminogenic, fluorogenic, phosphorescent, or fluors in combination with moieties that can suppress emission by fluorescence energy transfer (FET). Numerous methods are available for the detection of nucleic acids containing any of the above-listed labels. For example, biotin-labeled oligonucleotide(s) may be detected using non-isotopic detection methods which employ streptavidin-alkaline phosphatase conjugates. Fluorescein-labelled oligonucleotide(s) may be detected using a fluorescein-imager.

It is also contemplated that labelled oligonucleotides (cleaved or uncleaved) may be separated by means other than electrophoresis. For example, biotin-labelled oligonucleotides may be separated from nucleic acid present in the reaction mixture using para-magnetic or magnetic beads, or particles which are coated with avidin (or streptavidin). In this manner, the biotinylated oligonucleotide/avidin-magnetic bead complex can be physically separated from the other components in the mixture by exposing the complexes to a magnetic field. Additionally, the signal from the cleaved oligonucleotides may be resolved from that of the uncleaved oligonucleotides without physical separation. For example, a change in size, and therefore rate of rotation in solution of fluorescent molecules can be detected by fluorescence polarization analysis.

In a preferred embodiment, the reaction conditions comprise a cleavage reaction temperature which is less than the melting temperature of the first oligonucleotide and greater than the melting temperature of the 3' portion of the first oligonucleotide. In a particularly preferred embodiment, the reaction temperature is between approximately 40-65°C. It is contemplated that the reaction temperature at which the cleavage reaction occurs be selected with regard to the guidelines provided in the Description of the Invention.

The invention is not limited by the nature of the oligonucleotides employed. Using a target RNA, the oligonucleotides may comprise DNA, RNA or an oligonucleotide comprising a mixture of RNA and DNA.

The invention also contemplates the use of a second oligonucleotide (*i.e.*, the upstream oligonucleotide) which comprises a functional group (*e.g.*, a 5' peptide region) which prevents the dissociation of the 5' portion of the second oligonucleotide from the first region of the target RNA. When such a functional group is present on the second oligonucleotide, the interaction between the 3' portion of the second oligonucleotide and the first region of the target RNA may be destabilized (*i.e.*, designed to have a lower local melting temperature) through the use of A-T (or A-U) rich sequences, base analogs that form fewer hydrogen bonds (*e.g.*, dG-dU pairs) or through the use of phosphorothioate backbones, in order to allow the 5' region of the first oligonucleotide to compete successfully for hybridization.

The present invention utilizes structure-specific nucleases in methods for detection and characterization of nucleic acid sequences and sequence changes. The present invention also relates to means for cleaving a nucleic acid cleavage structure in a site-specific manner. Nuclease activity is used to screen for known and unknown mutations, including single base changes, in nucleic acids.

The invention is not limited to use of oligonucleotides which are completely complementary to their cognate target sequences. In one embodiment, both the first and second oligonucleotides are completely complementary to the target RNA. In another embodiment, the first oligonucleotide is partially complementary to the target RNA. In yet another embodiment, the second oligonucleotide is partially complementary to the target RNA. In yet another embodiment, both the first and the second oligonucleotide are partially complementary to the target RNA.

In a preferred embodiment, the methods of the invention employ a source of target RNA which comprises a sample selected from the group including, but not limited to blood, saliva, cerebral spinal fluid, pleural fluid, milk, lymph, sputum and semen.

In a preferred embodiment, the method employs reaction conditions which comprise providing a source of divalent cations. In a particularly preferred embodiment, the divalent cation is selected from the group comprising Mn^{2+} and Mg^{2+} ions.

5 The novel detection methods of the invention may be employed for the detection of target RNAs including, but not limited to, target RNAs comprising wild type and mutant alleles of genes, including genes from humans or other animals that are or may be associated with disease or cancer. In addition, the methods of the invention may be used for the detection of and/or identification of strains of microorganisms, including bacteria, fungi, protozoa, ciliates and viruses (and in particular for the detection and identification of RNA
10 viruses, such as HCV).

The present invention further provides a method of separating nucleic acid molecules, comprising: a) providing: i) a charge-balanced oligonucleotide and ii) a reactant; b) mixing the charge-balanced oligonucleotide with the reactant to create a reaction mixture under conditions such that a charge-unbalanced oligonucleotide is produced; and c) separating the
15 charge-unbalanced oligonucleotide from the reaction mixture.

The method of the present invention is not limited by the nature of the reactant employed. In a preferred embodiment the reactant comprises a cleavage means. In a particularly preferred embodiment, the cleavage means is an endonuclease. In another embodiment, the cleavage means is an exonuclease. In a still further embodiment, the
20 reactant comprises a polymerization means. In another embodiment, the reactant comprises a ligation means.

In a preferred embodiment, the charge-balanced oligonucleotide comprises a label. The invention is not limited by the nature of the label chosen, including, but not limited to, labels which comprise a dye or a radionucleotide (e.g., ^{32}P), fluorescein moiety, a biotin
25 moiety, luminogenic, fluorogenic, phosphorescent, or fluors in combination with moieties that can suppress emission by fluorescence energy transfer (FET). The label may be a charged moiety or alternatively may be a charge neutral moiety.

In another preferred embodiment, the charge-balanced oligonucleotide comprises one or more phosphonate groups. In a preferred embodiment, the phosphonate group is a
30 methylphosphonate group.

In one embodiment, the charge-balanced oligonucleotide has a net neutral charge and the charge-unbalanced oligonucleotide has a net positive charge. Alternatively, the charge-balanced oligonucleotide has a net neutral charge and the charge-unbalanced oligonucleotide

has a net negative charge. In yet another alternative embodiment, the charge-balanced oligonucleotide has a net negative charge and the charge-unbalanced oligonucleotide has a net positive charge. In another embodiment, the charge-balanced oligonucleotide has a net negative charge and the charge-unbalanced oligonucleotide has a net neutral charge. In
5 another preferred embodiment, the charge-balanced oligonucleotide has a net positive charge and the charge-unbalanced oligonucleotide has a net neutral charge. Still further, the charge-balanced oligonucleotide has a net positive charge and the charge-unbalanced oligonucleotide has a net negative charge.

In a preferred embodiment, the charge-balanced oligonucleotide comprises DNA
10 containing one or more positively charged adducts. In a preferred embodiment, the charge-balanced oligonucleotide comprises DNA containing one or more positively charged adducts and the cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net positive charge. In another preferred embodiment, the
15 charge-balanced oligonucleotide comprises DNA containing one or more positively charged adducts and the cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net neutral charge. Still further, the charge-balanced oligonucleotide comprises DNA containing one or more positively charged adducts and the
20 cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net negative charge.

In a preferred embodiment, the charge-balanced oligonucleotide comprises DNA containing one or more negatively charged adducts (*e.g.*, negatively charged amino acids).
25 Examples of negative charged adducts include negatively charged amino acids (*e.g.*, aspartate and glutamate). In a preferred embodiment, the charge-balanced oligonucleotide comprises DNA containing one or more negatively charged adducts and the cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net negative
30 charge. In a preferred embodiment, the charge-balanced oligonucleotide comprises DNA containing one or more negatively charged adducts and the cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net neutral charge. In a

preferred embodiment, the charge-balanced oligonucleotide comprises DNA containing one or more negatively charged adducts and the cleavage means removes one or more nucleotides from the charge-balanced oligonucleotide to produce the charge-unbalanced oligonucleotide, wherein the charge-unbalanced oligonucleotide has a net negative charge.

5 The present invention is not limited by the nature of the positively charged adduct(s) employed. In a preferred embodiment, the positively charged adducts are selected from the group consisting of indodicarbocyanine dyes (e.g., Cy3 and Cy5), amino-substituted nucleotides, ethidium bromide, ethidium homodimer, (1,3-propanediamino)propidium, (diethylenetriamino)propidium, thiazole orange, (N-N'-tetramethyl-1,3-propanediamino)propyl
10 thiazole orange, (N-N'-tetramethyl-1,2-ethanediamino)propyl thiazole orange, thiazole orange-thiazole orange homodimer (TOTO), thiazole orange-thiazole blue heterodimer (TOTAB), thiazole orange-ethidium heterodimer 1 (TOED1), thiazole orange-ethidium heterodimer 2 (TOED2), florescien-ethidium heterodimer (FED) and positively charged amino acids.

15 In another preferred embodiment, the separating step comprises subjecting the reaction mixture to an electrical field comprising a positive pole and a negative pole under conditions such that the charge-unbalanced oligonucleotide migrates toward the positive pole (*i.e.*, electrode). In another embodiment, the separating step comprises subjecting the reaction mixture to an electrical field comprising a positive pole and a negative pole under conditions such that the charge-unbalanced oligonucleotide migrates toward the negative pole.

20 In still further embodiment, the method of the present invention further comprises detecting the presence of the separated charge-unbalanced oligonucleotide. The present invention is not limited by the detection method employed: the method of detection chosen will vary depending on the nature of the label employed (if one is employed).

25 The present invention further comprises a method of detecting cleaved nucleic molecules, comprising: a) providing: i) a homogeneous plurality of charge-balanced oligonucleotides; ii) a sample suspected of containing a target nucleic acid having a sequence comprising a first region complementary to said charge-balanced oligonucleotide; iii) a cleavage means; and iv) a reaction vessel; b) adding to said vessel, in any order, the sample, the charge-balanced oligonucleotides and the cleavage means to create a reaction mixture
30 under conditions such that a portion of the charge-balanced oligonucleotides binds to the complementary target nucleic acid to create a bound (*i.e.*, annealed) population, and such that the cleavage means cleaves at least a portion of said bound population of charge-balanced

oligonucleotides to produce a population of unbound, charge-unbalanced oligonucleotides; and
c) separating the unbound, charge-unbalanced oligonucleotides from the reaction mixture.

In a preferred embodiment, the method further comprises providing a homogeneous plurality of oligonucleotides complementary to a second region of the target nucleic acid,
5 wherein the oligonucleotides are capable of binding to the target nucleic acid upstream of the charge-balanced oligonucleotides. In another preferred embodiment, the first and the second region of the target nucleic acid share a region of overlap.

The invention is not limited by the nature of the cleavage means employed. In one embodiment, the cleavage means comprises a thermostable 5' nuclease. In a preferred
10 embodiment, a portion of the amino acid sequence of the 5' nuclease is homologous to a portion of the amino acid sequence of a thermostable DNA polymerase derived from a thermophilic organism. In a preferred embodiment, the organism is selected from the group consisting of *Thermus aquaticus*, *Thermus flavus* and *Thermus thermophilus*. In another preferred embodiment, the nuclease is encoded by a DNA sequence selected from the group
15 consisting of SEQ ID NOS:1-3, 9, 10, 12, 21, 25 and 26.

The invention is not limited by the nature of the target nucleic acid. The target nucleic acid may comprise single-stranded DNA, double-stranded DNA or RNA. In a preferred embodiment, the target nucleic acid comprises double-stranded DNA and prior to the addition of the cleavage means the reaction mixture is treated such that the double-
20 stranded DNA is rendered substantially single-stranded preferably by increasing the temperature.

The invention further provides a method of separating nucleic acid molecules, comprising: a) modifying an oligonucleotide so as to produce a charge-balanced oligonucleotide; b) providing: i) a said charge-balanced oligonucleotide and ii) a reactant;
25 c) mixing said charge-balanced oligonucleotide with said reactant to create a reaction mixture under conditions such that a charge-unbalanced oligonucleotide is produced; and d) separating said charge-unbalanced oligonucleotide from said reaction mixture.

The invention is not limited by the nature of the modification. In a preferred embodiment, the modifying step comprises the covalent attachment of a positively charged adduct to one or bases of the oligonucleotide. In another preferred embodiment, the
30 modifying step comprises the covalent attachment of a negatively charged adduct to one or bases of the oligonucleotide. In a still further embodiment, the modifying comprises the incorporation of one or more amino-substituted bases during synthesis of the oligonucleotide.

In another embodiment, the modifying comprises the incorporation of one or more phosphonate groups during synthesis of said oligonucleotide. In a preferred embodiment, the phosphonate group is a methylphosphonate group.

The invention further provides a method of treating a nucleic acid molecule,
5 comprising: a) providing: i) a charge-balanced oligonucleotide and ii) a reactant; b) mixing said charge-balanced oligonucleotide with said reactant to create a reaction mixture under conditions such that a charge-unbalanced oligonucleotide is produced.

The invention further provides a method of treating a nucleic acid molecule,
10 comprising: a) modifying an oligonucleotide so as to produce a charge-balanced oligonucleotide; b) providing: i) said charge-balanced oligonucleotide and ii) a reactant; c) mixing the charge-balanced oligonucleotide with the reactant to create a reaction mixture under conditions such that a charge-unbalanced oligonucleotide is produced.

The present invention provides a composition comprising a cleavage structure, said
15 cleavage structure comprising: a) a target nucleic acid, said target nucleic acid having a first region, a second region, a third region and a fourth region, wherein said first region is located adjacent to and downstream from said second region, said second region is located adjacent to and downstream from said third region and said third region is located adjacent to and downstream from said fourth region; b) a first oligonucleotide complementary to said fourth
20 region of said target nucleic acid; c) a second oligonucleotide having a 5' portion and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said third region of said target nucleic acid; and d) a third oligonucleotide having a 5' portion and a 3' portion
25 wherein said 5' portion of said third oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said third oligonucleotide contains a sequence complementary to said second region of said target nucleic acid.

The present invention is not limited by the length of the four regions of the target
30 nucleic acid. In one embodiment, the first region of the target nucleic acid has a length of 11 to 50 nucleotides. In another embodiment, the second region of the target nucleic acid has a length of one to three nucleotides. In another embodiment, the third region of the target nucleic acid has a length of six to nine nucleotides. In yet another embodiment, the fourth region of the target nucleic acid has a length of 6 to 50 nucleotides.

The invention is not limited by the nature or composition of the of the first, second, third and fourth oligonucleotides: these oligonucleotides may comprise DNA, RNA, PNA and combinations thereof as well as comprise modified nucleotides, universal bases, adducts, etc. Further, one or more of the first, second, third and the fourth oligonucleotides may contain a
5 dideoxynucleotide at the 3' terminus.

In a preferred embodiment, the target nucleic acid is not completely complementary to at least one of the first, the second, the third and the fourth oligonucleotides. In a particularly preferred embodiment, the target nucleic acid is not completely complementary to the second oligonucleotide.

10 As noted above, the present invention contemplates the use of structure-specific nucleases in a detection method. In one embodiment, the present invention provides a method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising: a) providing: i) a cleavage means, ii) a source of target nucleic acid, the target nucleic acid having a first region, a second region, a third region and a fourth region,
15 wherein the first region is located adjacent to and downstream from the second region, the second region is located adjacent to and downstream from the third region and the third region is located adjacent to and downstream from the fourth region: iii) a first oligonucleotide complementary to the fourth region of the target nucleic acid: iv) a second oligonucleotide having a 5' portion and a 3' portion wherein the 5' portion of the second
20 oligonucleotide contains a sequence complementary to the second region of said target nucleic acid and wherein the 3' portion of the second oligonucleotide contains a sequence complementary to the third region of the target nucleic acid: iv) a third oligonucleotide having a 5' and a 3' portion wherein the 5' portion of the third oligonucleotide contains a sequence complementary to the first region of the target nucleic acid and wherein the 3' portion of the
25 third oligonucleotide contains a sequence complementary to the second region of the target nucleic acid: b) mixing the cleavage means, the target nucleic acid, the first oligonucleotide, the second oligonucleotide and the third oligonucleotide to create a reaction mixture under reaction conditions such that the first oligonucleotide is annealed to the fourth region of the target nucleic acid and wherein at least the 3' portion of the second oligonucleotide is
30 annealed to the target nucleic acid and wherein at least the 5' portion of the third oligonucleotide is annealed to the target nucleic acid so as to create a cleavage structure and wherein cleavage of the cleavage structure occurs to generate non-target cleavage products,

each non-target cleavage product having a 3'-hydroxyl group; and c) detecting the non-target cleavage products.

The invention is not limited by the nature of the target nucleic acid. In one embodiment, the target nucleic acid comprises single-stranded DNA. In another embodiment, the target nucleic acid comprises double-stranded DNA and prior to step c), the reaction mixture is treated such that the double-stranded DNA is rendered substantially single-stranded. In another embodiment, the target nucleic acid comprises RNA and the first and second oligonucleotides comprise DNA.

The invention is not limited by the nature of the cleavage means. In one embodiment, the cleavage means is a structure-specific nuclease; particularly preferred structure-specific nucleases are thermostable structure-specific nucleases. In a preferred embodiment, the thermostable structure-specific nuclease is encoded by a DNA sequence selected from the group consisting of SEQ ID NOS:1-3, 9, 10, 12, 21, 25, 26, 60, 65, 68, 70, 74, and 78. In another preferred embodiment, the thermostable structure-specific nuclease is a nuclease from the FEN-1/RAD2/XPG class of nucleases.

In a preferred embodiment, the detection of the non-target cleavage products comprises electrophoretic separation of the products of the reaction followed by visualization of the separated non-target cleavage products.

In another preferred embodiment, one or more of the first, second, and third oligonucleotides contain a dideoxynucleotide at the 3' terminus. When dideoxynucleotide-containing oligonucleotides are employed, the detection of the non-target cleavage products preferably comprises: a) incubating said non-target cleavage products with a template-independent polymerase and at least one labelled nucleoside triphosphate under conditions such that at least one labelled nucleotide is added to the 3'-hydroxyl group of said non-target cleavage products to generate labelled non-target cleavage products; and b) detecting the presence of said labelled non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label, the 5' end label being a different label than the label present upon the labelled nucleoside triphosphate. The invention is not limited by the nature of the 5' end label; a wide variety of suitable 5' end

labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3, Cy5 and digoxigenin.

In another embodiment, detecting the non-target cleavage products comprises: a) incubating said non-target cleavage products with a template-independent polymerase and at least one nucleoside triphosphate under conditions such that at least one nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate tailed non-target cleavage products; and b) detecting the presence of the tailed non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed; in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label. The invention is not limited by the nature of the 5' end label: a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3, Cy5 and digoxigenin.

In a preferred embodiment, the reaction conditions comprise providing a source of divalent cations; particularly preferred divalent cations are Mn^{2+} and Mg^{2+} ions.

The present invention further provides a method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising: a) providing: i) a cleavage means, ii) a source of target nucleic acid, said target nucleic acid having a first region, a second region and a third region, wherein said first region is located adjacent to and downstream from said second region and wherein said second region is located adjacent to and downstream from said third region; iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide contains a sequence complementary to said second region of said target nucleic acid and wherein said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said target nucleic acid; iv) a second oligonucleotide having a length between eleven to fifteen nucleotides and further having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid; b) mixing said cleavage means, said target nucleic acid, said first oligonucleotide and said second oligonucleotide to create a reaction mixture under reaction conditions such that at least said 3' portion of said first oligonucleotide is annealed to said target nucleic acid and wherein at least said 5' portion

of said second oligonucleotide is annealed to said target nucleic acid so as to create a cleavage structure and wherein cleavage of said cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and c) detecting said non-target cleavage products. In a preferred embodiment the cleavage means is a structure-specific nuclease, preferably a thermostable structure-specific nuclease.

The invention is not limited by the length of the various regions of the target nucleic acid. In a preferred embodiment, the second region of said target nucleic acid has a length between one to five nucleotides. In another preferred embodiment, one or more of the first and the second oligonucleotides contain a dideoxynucleotide at the 3' terminus. When dideoxynucleotide-containing oligonucleotides are employed, the detection of the non-target cleavage products preferably comprises: a) incubating said non-target cleavage products with a template-independent polymerase and at least one labelled nucleoside triphosphate under conditions such that at least one labelled nucleotide is added to the 3'-hydroxyl group of said non-target cleavage products to generate labelled non-target cleavage products; and b) detecting the presence of said labelled non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed: in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label, the 5' end label being a different label than the label present upon the labelled nucleoside triphosphate. The invention is not limited by the nature of the 5' end label: a wide variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3, Cy5 and digoxigenin.

In another embodiment, detecting the non-target cleavage products comprises: a) incubating said non-target cleavage products with a template-independent polymerase and at least one nucleoside triphosphate under conditions such that at least one nucleotide is added to the 3'-hydroxyl group of the non-target cleavage products to generate tailed non-target cleavage products; and b) detecting the presence of the tailed non-target cleavage products. The invention is not limited by the nature of the template-independent polymerase employed: in one embodiment, the template-independent polymerase is selected from the group consisting of terminal deoxynucleotidyl transferase (TdT) and poly A polymerase. When TdT or polyA polymerase are employed in the detection step, the second oligonucleotide may contain a 5' end label. The invention is not limited by the nature of the 5' end label; a wide

variety of suitable 5' end labels are known to the art and include biotin, fluorescein, tetrachlorofluorescein, hexachlorofluorescein, Cy3, Cy5 and digoxigenin.

The novel detection methods of the invention may be employed for the detection of target DNAs and RNAs including, but not limited to, target DNAs and RNAs comprising wild type and mutant alleles of genes, including genes from humans or other animals that are or may be associated with disease or cancer. In addition, the methods of the invention may be used for the detection of and/or identification of strains of microorganisms, including bacteria, fungi, protozoa, ciliates and viruses (and in particular for the detection and identification of RNA viruses, such as HCV).

The present invention further provides a composition, comprising: a) a first single continuous strand of nucleic acid, having a first and a second portion, comprising a sequence defining the template strand of a protein binding region; b) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to said first portion of said protein binding region; c) a third single continuous strand of nucleic acid having a 5' and a 3' end, said third nucleic acid comprising a region complementary to said second portion of said protein binding region; and wherein said second and said third nucleic acids are annealed to said protein binding region such that a complete double-stranded protein binding region is formed. The present invention is not limited by the nature of the protein binding region employed. In a preferred embodiment, the protein binding region is a template-dependent RNA polymerase binding region, preferably the T7 RNA polymerase binding region.

In a preferred embodiment, the annealed second and third nucleic acids are further annealed to one another. In another embodiment, the second nucleic acid comprises a single-stranded 3' tail that is not capable of annealing to said first nucleic acid. In yet another embodiment, the third nucleic acid comprises a single-stranded 5' tail that is not capable of annealing to the first nucleic acid. In a still further embodiment, at least one of said second and said third nucleic acids comprises a region that is not annealed to the first nucleic acid. When at least one of said second and said third nucleic acids comprises a region that is not annealed to the first nucleic acid, the second nucleic acid may comprise a single-stranded 3' tail that is not annealed to the first nucleic acid and the third nucleic acid may comprise a single-stranded 5' tail that is not annealed to the first nucleic acid.

In another embodiment, the present invention provides a composition, comprising: a) a first single continuous strand of nucleic acid, having a first and a second portion, comprising

a sequence defining the template strand of a protein binding region; b) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to said first portion of said protein binding region; c) a third single continuous strand of nucleic acid having a 5' and a 3' end, said third nucleic acid comprising a region complementary to said second portion of said protein binding region; and wherein said second and said third nucleic acids are annealed to said protein binding region such that a complete double-stranded protein binding region is formed and wherein the 3' end of said annealed second nucleic acid abuts the 5' end of said annealed third nucleic acid.

The invention also provides a method of producing RNA transcripts, comprising: a) providing a composition comprising: i) a first single continuous strand of nucleic acid comprising a sequence defining the template strand of an RNA polymerase binding region; ii) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to a first portion of said first nucleic acid; iii) a third single continuous strand of nucleic acid having a 5' and a 3' end, said third nucleic acid comprising a region complementary to a second portion of said first nucleic acid; and wherein said second and said third nucleic acids are annealed to said first nucleic acid such that a complete double-stranded RNA polymerase binding region is formed; and b) exposing said composition to conditions such that transcription occurs.

The invention further provides a method of detecting the non-target cleavage products produced in the Invader™-directed cleavage assay (e.g., Claims 25, 26, 29, 35-38 and 41-43) which comprises: a) providing: i) said non-target cleavage products; ii) a composition comprising two single-stranded nucleic acids annealed so as to define a single-stranded portion of a protein binding region; iii) a nucleic acid producing protein; b) exposing said non-target cleavage products to said single-stranded portion of said protein binding region under conditions such that said nucleic acid producing protein binds to said protein binding region and produces nucleic acid. In a preferred embodiment, the single-stranded portion of the protein binding region comprises: a) a first single continuous strand of nucleic acid comprising a sequence defining the template strand of an RNA polymerase binding region; and b) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to a portion of said first nucleic acid, wherein said second nucleic acid is annealed to said first nucleic acid so as to define said single-stranded portion of said protein binding region.

The invention is not limited by the nature of the protein binding region employed. In a preferred embodiment, the protein binding region is a template-dependent RNA polymerase binding region, more preferably the T7 RNA polymerase binding region.

The invention further provides a method of detecting the non-target cleavage products produced in the Invader™-directed cleavage assay (e.g., Claims 25, 26, 29, 35-38 and 41-43) which comprises: a) providing: i) said non-target cleavage products; ii) a single continuous strand of nucleic acid comprising a sequence defining a single strand of an RNA polymerase binding region; iii) a template-dependent DNA polymerase; iv) a template-dependent RNA polymerase; b) exposing said non-target cleavage products to said RNA polymerase binding region under conditions such that said non-target cleavage product binds to a portion of said single strand of said RNA polymerase binding region; c) exposing said bound non-target cleavage product to said template-dependent DNA polymerase under conditions such that a double-stranded RNA polymerase binding region is produced; d) exposing said double-stranded RNA polymerase binding region to said template-dependent RNA polymerase under conditions such that RNA transcripts are produced. In a preferred embodiment, the method further comprises detecting the RNA transcripts.

The invention is not limited by the nature of the protein binding region employed. In a preferred embodiment, the protein binding region is a template-dependent RNA polymerase binding region, more preferably the T7 RNA polymerase binding region.

DESCRIPTION OF THE DRAWINGS

Fig. 1 is a comparison of the nucleotide structure of the DNAP genes isolated from *Thermus aquaticus* (SEQ ID NO:1), *Thermus flavus* (SEQ ID NO:2) and *Thermus thermophilus* (SEQ ID NO:3); the consensus sequence (SEQ ID NO:7) is shown at the top of each row.

Fig. 2 is a comparison of the amino acid sequence of the DNAP isolated from *Thermus aquaticus* (SEQ ID NO:4), *Thermus flavus* (SEQ ID NO:5), and *Thermus thermophilus* (SEQ ID NO:6); the consensus sequence (SEQ ID NO:8) is shown at the top of each row.

Figs. 3A-G are a set of diagrams of wild-type and synthesis-deficient DNAP_{Taq} genes.

Fig. 4A depicts the wild-type *Thermus flavus* polymerase gene.

Fig. 4B depicts a synthesis-deficient *Thermus flavus* polymerase gene.

Fig. 5 depicts a structure which cannot be amplified using DNAP*Taq*: this figure shows SEQ ID NO:17 (primer) and SEQ ID NO:15 (hairpin).

Fig. 6 is a ethidium bromide-stained gel demonstrating attempts to amplify a bifurcated duplex using either DNAP*Taq* or DNAP*Stf* (*i.e.*, the Stoffel fragment of DNAP*Taq*).

Fig. 7 is an autoradiogram of a gel analyzing the cleavage of a bifurcated duplex by DNAP*Taq* and lack of cleavage by DNAP*Stf*.

Figs. 8A-B are a set of autoradiograms of gels analyzing cleavage or lack of cleavage upon addition of different reaction components and change of incubation temperature during attempts to cleave a bifurcated duplex with DNAP*Taq*.

Figs. 9A-B are an autoradiogram displaying timed cleavage reactions, with and without primer.

Figs. 10A-B are a set of autoradiograms of gels demonstrating attempts to cleave a bifurcated duplex (with and without primer) with various DNAPs.

Fig. 11A shows the substrate and oligonucleotides [19-12 (SEQ ID NO:18) and 30-12 (SEQ ID NO:19)] used to test the specific cleavage of substrate DNAs targeted by pilot oligonucleotides.

Fig. 11B shows an autoradiogram of a gel showing the results of cleavage reactions using the substrates and oligonucleotides shown Fig. 12A.

Fig. 12A shows the substrate and oligonucleotide [30-0 (SEQ ID NO:20)] used to test the specific cleavage of a substrate RNA targeted by a pilot oligonucleotide.

Fig. 12B shows an autoradiogram of a gel showing the results of a cleavage reaction using the substrate and oligonucleotide shown in Fig. 13A.

Fig. 13 is a diagram of vector pTTQ18.

Fig. 14 is a diagram of vector pET-3c.

Figs. 15A-E depicts a set of molecules which are suitable substrates for cleavage by the 5' nuclease activity of DNAPs (SEQ ID NOS:15 and 17 are depicted in Fig.15E).

Fig. 16 is an autoradiogram of a gel showing the results of a cleavage reaction run with synthesis-deficient DNAPs.

Fig. 17 is an autoradiogram of a PEI chromatogram resolving the products of an assay for synthetic activity in synthesis-deficient DNAP*Taq* clones.

Fig. 18A depicts the substrate molecule (SEQ ID NOS:15 and 17) used to test the ability of synthesis-deficient DNAPs to cleave short hairpin structures.

Fig. 18B shows an autoradiogram of a gel resolving the products of a cleavage reaction run using the substrate shown in Fig. 19A.

Fig. 19 provides the complete 206-mer duplex sequence (SEQ ID NO:27) employed as a substrate for the 5' nucleases of the present invention

5 Figs. 20A and B show the cleavage of linear nucleic acid substrates (based on the 206-mer of Fig. 21) by wild type DNAPs and 5' nucleases isolated from *Thermus aquaticus* and *Thermus flavus*.

Fig. 21A shows the "nibbling" phenomenon detected with the DNAPs of the present invention.

10 Fig. 21B shows that the "nibbling" of Fig. 25A is 5' nucleolytic cleavage and not phosphatase cleavage.

Fig. 22 demonstrates that the "nibbling" phenomenon is duplex dependent.

Fig. 23 is a schematic showing how "nibbling" can be employed in a detection assay.

Figs. 24A and B demonstrates that "nibbling" can be target directed.

15 Fig. 25 provides a schematic drawing of a target nucleic acid with an invader oligonucleotide and a probe oligonucleotide annealed to the target.

Fig. 26 provides a schematic showing the S-60 hairpin oligonucleotide (SEQ ID NO:29) with the annealed P-15 oligonucleotide (SEQ ID NO:30).

20 Fig. 27 is an autoradiogram of a gel showing the results of a cleavage reaction run using the S-60 hairpin in the presence or absence of the P-15 oligonucleotide.

Fig. 28 provides a schematic showing three different arrangements of target-specific oligonucleotides and their hybridization to a target nucleic acid which also has a probe oligonucleotide annealed thereto (SEQ ID NOS:31-35).

25 Fig. 29 is the image generated by a fluorescence imager showing that the presence of an invader oligonucleotide causes a shift in the site of cleavage in a probe/target duplex.

Fig. 30 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run using the three target-specific oligonucleotides diagrammed in Fig. 28.

30 Fig. 31 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence or absence of non-target nucleic acid molecules.

Fig. 32 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence of decreasing amounts of target nucleic acid.

5 Fig. 33 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence or absence of saliva extract using various thermostable 5' nucleases or DNA polymerases.

Fig. 34 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run using various 5' nucleases.

10 Fig. 35 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run using two target nucleic acids which differ by a single basepair at two different reaction temperatures.

Fig. 36A provides a schematic showing the effect of elevated temperature upon the annealing and cleavage of a probe oligonucleotide along a target nucleic acid wherein the probe contains a region of noncomplementarity with the target.

15 Fig. 36B provides a schematic showing the effect of adding an upstream oligonucleotide upon the annealing and cleavage of a probe oligonucleotide along a target nucleic acid wherein the probe contains a region of noncomplementarity with the target.

Fig. 37 provides a schematic showing an arrangement of a target-specific invader oligonucleotide (SEQ ID NO:39) and a target-specific probe oligonucleotide (SEQ ID NO:38) bearing a 5' Cy3 label along a target nucleic acid (SEQ ID NO:31).

Fig. 38 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence of increasing concentrations of KCl.

25 Fig. 39 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence of increasing concentrations of MnCl₂ or MgCl₂.

Fig. 40 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run in the presence of increasing amounts of genomic DNA or tRNA.

30 Fig. 41 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run use a HCV RNA target.

Fig. 42 is the image generated by a fluorescence imager showing the products of invader-directed cleavage assays run using a HCV RNA target and demonstrate the stability of RNA targets under invader-directed cleavage assay conditions.

Fig. 43 is the image generated by a fluorescence imager showing the sensitivity of detection and the stability of RNA in invader-directed cleavage assays run using a HCV RNA target.

Fig. 44 is the image generated by a fluorescence imager showing thermal degradation of oligonucleotides containing or lacking a 3' phosphate group.

Fig. 45 depicts the structure of amino-modified oligonucleotides 70 and 74.

Fig. 46 depicts the structure of amino-modified oligonucleotide 75

Fig. 47 depicts the structure of amino-modified oligonucleotide 76.

Fig. 48 is the image generated by a fluorescence imager scan of an IEF gel showing the migration of substrates 70, 70dp, 74, 74dp, 75, 75dp, 76 and 76dp.

Fig. 49A provides a schematic showing an arrangement of a target-specific invader oligonucleotide (SEQ ID NO:50) and a target-specific probe oligonucleotide (SEQ ID NO:51) bearing a 5' Cy3 label along a target nucleic acid (SEQ ID NO:52).

Fig. 49B is the image generated by a fluorescence imager showing the detection of specific cleavage products generated in an invasive cleavage assay using charge reversal (*i.e.*, charge based separation of cleavage products).

Fig. 50 is the image generated by a fluorescence imager which depicts the sensitivity of detection of specific cleavage products generated in an invasive cleavage assay using charge reversal.

Fig. 51 depicts a first embodiment of a device for the charge-based separation of oligonucleotides.

Fig. 52 depicts a second embodiment of a device for the charge-based separation of oligonucleotides.

Fig. 53 shows an autoradiogram of a gel showing the results of cleavage reactions run in the presence or absence of a primer oligonucleotide; a sequencing ladder is shown as a size marker.

Figs. 54A-D depict four pairs of oligonucleotides: in each pair shown, the upper arrangement of a probe annealed to a target nucleic acid lacks an upstream oligonucleotide and the lower arrangement contains an upstream oligonucleotide (SEQ ID NOS:32 and 54-58 are shown in Figs. 54A-D).

Fig. 55 shows the chemical structure of several positively charged heterodimeric DNA-binding dyes.

Fig. 56 is a schematic showing alternative methods for the tailing and detection of specific cleavage products in the context of the Invader™-directed cleavage assay.

Fig. 57 provides a schematic drawing of a target nucleic acid with an Invader™ oligonucleotide, a miniprobe, and a stacker oligonucleotide annealed to the target.

5 Fig. 58 provides a space-filling model of the 3-dimensional structure of the T5 5'-exonuclease.

Fig. 59 provides an alignment of the amino acid sequences of several FEN-1 nucleases including the *Methanococcus jannaschii* FEN-1 protein (MJAFEN1.PRO), the *Pyrococcus furiosus* FEN-1 protein (PFUFEN1.PRO), the human FEN-1 protein (HUMFEN1.PRO), the
10 mouse FEN-1 protein (MUSFEN1.PRO), the *Saccharomyces cerevisiae* YKL510 protein (YST510.PRO), the *Saccharomyces cerevisiae* RAD2 protein (YSTRAD2.PRO), the *Shizosaccharomyces pombe* RAD13 protein (SPORAD13.PRO), the human XPG protein (HUMXPG.PRO), the mouse XPG protein (MUSXPG.PRO), the *Xenopus laevis* XPG protein (XENXPG.PRO) and the *C. elegans* RAD2 protein (CELRAD2.PRO) (SEQ ID NOS:135-145.
15 respectively); portions of the amino acid sequence of some of these proteins were not shown in order to maximize the alignment between proteins (specifically, amino acids 122 to 765 of the YSTRAD2 sequence were deleted; amino acids 122 to 746 of the SPORAD13 sequence were deleted; amino acids 122 to 757 of the HUMXPG sequence were deleted; amino acids 122 to 770 of the MUSXPG sequence were deleted; and amino acids 122 to 790 of the
20 XENXPG sequence were deleted). The numbers to the left of each line of sequence refers to the amino acid residue number; dashes represent gaps introduced to maximize alignment.

Fig. 60 is a schematic showing the S-33 (SEQ ID NO:84) and 11-8-0 (SEQ ID NO:85) oligonucleotides in a folded configuration; the cleavage site is indicated by the arrowhead.

25 Fig. 61 shows a Coomassie stained SDS-PAGE gel showing the thrombin digestion of Cleavase® BN/thrombin.

Fig. 62 is the image generated by a fluorescence imager showing the products produced by the cleavage of the S-60 hairpin using Cleavase® BN/thrombin (before and after thrombin digestion).

30 Fig. 63 is the image generated by a fluorescence imager showing the products produced by the cleavage of circular M13 DNA using Cleavase® BN/thrombin.

Fig. 64 is an SDS-PAGE gel showing the migration of purified Cleavase® BN nuclease, *Pfu* FEN-1, *Pwo* FEN-1 and *Mja* FEN-1.

Fig. 65 is the image generated by a fluorescence imager showing the products produced by the cleavage of the S-33 and 11-8-0 oligonucleotides by Cleavase® BN and the *Mja* FEN-1 nucleases.

Fig. 66 is the image generated by a fluorescence imager showing the products produced by the incubation of an oligonucleotide either having or lacking a 3'-OH group with TdT.

Fig. 67 is the image generated by a fluorescence imager showing the products produced the incubation of cleavage products with TdT.

Fig. 68 is a photograph of a Universal GeneComb™ card showing the capture and detection of cleavage products on a nitrocellulose support.

Fig. 69 is the image generated by a fluorescence imager showing the products produced using the Cleavase® A/G and *Pfu* FEN-1 nucleases and a fluorescein-labeled probe.

Fig. 70 is the image generated by a fluorescence imager showing the products produced using the Cleavase® A/G and *Pfu* FEN-1 nucleases and a Cy3-labeled probe.

Fig. 71 is the image generated by a fluorescence imager showing the products produced using the Cleavase® A/G and *Pfu* FEN-1 nucleases and a TET-labeled probe.

Figs. 72A and 72B are images generated by a fluorescence imager showing the products produced using the Cleavase® A/G and *Pfu* FEN-1 nucleases and probes having or lacking a 5' positive charge; the gel shown in Fig. 83A was run in the standard direction and the gel shown in Fig. 84B was run in the reverse direction.

Fig. 73 shows the structure of 3-nitropyrrole and 5-nitroindole.

Fig. 74 shows the sequence of oligos 109, 61 and 67 (SEQ ID NOS:97, 50 and 51) annealed into a cleavage structure as well as the sequence of oligo 67 (SEQ ID NO:51) and a composite of SEQ ID NOS:98, 99, 101 and 102.

Fig. 75A-C show images generated by a fluorescence imager showing the products produced in an Invader™-directed cleavage assay performed at various temperatures using a miniprobe which is either completely complementary to the target or contains a single mismatch with the target.

Fig. 76 shows the sequence of oligos 166 (SEQ ID NO:103), 165 (SEQ ID NO:104), 161 (SEQ ID NO:106), 162 (SEQ ID NO:105) and 164 (SEQ ID NO:107) as well as a cleavage structure.

Fig. 77 shows the image generated by a fluorescence imager showing the products produced in an Invader™-directed cleavage assay performed using *ras* gene sequences as the target.

5 Figs. 78A-C show the sequence of the S-60 hairpin (SEQ ID NO:29) (A), and the P-15 oligo (SEQ ID NO:30) (shown annealed to the S-60 hairpin in B) and the image generated by a fluorescence imager showing the products produced by cleavage of the S-60 hairpin in the presence of various Invader™ oligos.

Fig. 79 shows the structure of various 3' end substituents.

10 Fig. 80 is a composite graph showing the effect of probe concentration, temperature and a stacker oligonucleotide on the cleavage of miniprobos.

Fig. 81 shows the sequence of the IT-2 oligonucleotide (SEQ ID NO:115; shown in a folded configuration) as well as the sequence of the IT-1 (SEQ ID NO:116) and IT-A (SEQ ID NO:117) oligos.

15 Fig. 82 shows the image generated by a fluorescence imager showing the products produced by cleavage of the oligos shown in Fig. 92 by Cleavase® A/G nuclease.

Fig. 83 shows the image generated by a fluorescence imager which provides a comparison of the rates of cleavage by the *Pfu* FEN-1 and *Mja* FEN-1 nucleases.

Fig. 84 shows the image generated by a fluorescence imager which depicts the detection of RNA targets using a miniprobe and stacker oligonucleotides.

20 Figs. 85A-C provide schematics showing particular embodiments of the present invention wherein a T7 promoter region and copy template annealed with either no oligo (A), a complete promoter oligo (B) or a complete promoter oligo with a 3' tail (C); one strand of the T7 promoter region is indicated by the hatched line.

25 Figs. 86A-D provide schematics showing particular embodiments of the present invention wherein a T7 promoter region and copy template annealed with either a cut probe(A), a partial promoter oligo (B), an uncut oligo (C) or both an uncut probe and a partial promoter oligo (D).

30 Fig. 87 provides a schematic illustrating one embodiment of the present invention wherein a template-dependent DNA polymerase is used to extend a cut probe to complete a T7 promoter region and thereby allow transcription.

Fig. 88 provides a schematic illustrating that an uncut probe combined with a partial promoter oligo does not permit transcription while a cut probe combined with a partial promoter oligo generates a complete (but nicked) promoter which supports transcription.

Fig. 89 shows the image generated by a fluorescence imager which shows that primer extension can be used to complete a partial promoter formed by a cut probe (lanes 1-5) and that annealing a cut probe generated in an invasive cleavage assay can complete a partial T7 promoter to permit transcription (lanes 6-9).

5 Figs. 90A-C provide schematics showing particular embodiments of the present invention which illustrate that the use of a partial promoter oligo with a paired 5' tail can be used to block transcription from a composite promoter formed by the annealing of an uncut probe.

10 Fig. 91 shows the image generated by a fluorescence imager which shows that transcription from a "leaky" branched T7 composite promoter can be shut down by the use of a downstream partial promoter oligo having a paired 5' tail.

Fig. 92 shows the image generated by a fluorescence imager which shows that the location of the nick site in a nicked composite T7 promoter can effect the efficiency of transcription.

15 Fig. 93 shows the image generated by a fluorescence imager which shows that the presence of an unpaired 3' tail on a full-length promoter oligo decreases but does not abolish transcription. Beneath the image are schematics showing the nucleic acids tested in reactions 1-4; these schematics show SEQ ID NOS:123-125.

20 Fig. 94 is a schematic which illustrates one embodiment of the present invention where a composite T7 promoter region is created by the binding of the cut probe oligo downstream of the partial promoter oligo.

Figs. 95A-D provide schematics showing particular embodiments of the present invention which show various ways in which a composite promoter can be formed wherein the nick is located in the template (or bottom) strand.

25 DEFINITIONS

As used herein, the terms "complementary" or "complementarity" are used in reference to polynucleotides (*i.e.*, a sequence of nucleotides such as an oligonucleotide or a target nucleic acid) related by the base-pairing rules. For example, for the sequence "A-G-T," is
30 complementary to the sequence "T-C-A." Complementarity may be "partial," in which only some of the nucleic acids' bases are matched according to the base pairing rules. Or, there may be "complete" or "total" complementarity between the nucleic acids. The degree of complementarity between nucleic acid strands has significant effects on the efficiency and

strength of hybridization between nucleic acid strands. This is of particular importance in amplification reactions, as well as detection methods which depend upon binding between nucleic acids.

5 The term "homology" refers to a degree of identity. There may be partial homology or complete homology. A partially identical sequence is one that is less than 100% identical to another sequence.

As used herein, the term "hybridization" is used in reference to the pairing of complementary nucleic acids. Hybridization and the strength of hybridization (*i.e.*, the strength of the association between the nucleic acids) is impacted by such factors as the degree of complementary between the nucleic acids, stringency of the conditions involved, the T_m of the formed hybrid, and the G:C ratio within the nucleic acids.

As used herein, the term " T_m " is used in reference to the "melting temperature." The melting temperature is the temperature at which a population of double-stranded nucleic acid molecules becomes half dissociated into single strands. The equation for calculating the T_m of nucleic acids is well known in the art. As indicated by standard references, a simple estimate of the T_m value may be calculated by the equation: $T_m = 81.5 + 0.41(\% G + C)$, when a nucleic acid is in aqueous solution at 1 M NaCl (*see e.g.*, Anderson and Young, Quantitative Filter Hybridization, in *Nucleic Acid Hybridization* (1985). Other references include more sophisticated computations which take structural as well as sequence characteristics into account for the calculation of T_m .

As used herein the term "stringency" is used in reference to the conditions of temperature, ionic strength, and the presence of other compounds, under which nucleic acid hybridizations are conducted. With "high stringency" conditions, nucleic acid base pairing will occur only between nucleic acid fragments that have a high frequency of complementary base sequences. Thus, conditions of "weak" or "low" stringency are often required when it is desired that nucleic acids which are not completely complementary to one another be hybridized or annealed together.

The term "gene" refers to a DNA sequence that comprises control and coding sequences necessary for the production of a polypeptide or precursor. The polypeptide can be encoded by a full length coding sequence or by any portion of the coding sequence so long as the desired enzymatic activity is retained.

The term "wild-type" refers to a gene or gene product which has the characteristics of that gene or gene product when isolated from a naturally occurring source. A wild-type gene

is that which is most frequently observed in a population and is thus arbitrarily designed the "normal" or "wild-type" form of the gene. In contrast, the term "modified" or "mutant" refers to a gene or gene product which displays modifications in sequence and or functional properties (*i.e.*, altered characteristics) when compared to the wild-type gene or gene product.

5 It is noted that naturally-occurring mutants can be isolated; these are identified by the fact that they have altered characteristics when compared to the wild-type gene or gene product.

The term "recombinant DNA vector" as used herein refers to DNA sequences containing a desired coding sequence and appropriate DNA sequences necessary for the expression of the operably linked coding sequence in a particular host organism. DNA
10 sequences necessary for expression in procaryotes include a promoter, optionally an operator sequence, a ribosome binding site and possibly other sequences. Eukaryotic cells are known to utilize promoters, polyadenylation signals and enhancers.

The term "LTR" as used herein refers to the long terminal repeat found at each end of a provirus (*i.e.*, the integrated form of a retrovirus). The LTR contains numerous regulatory
15 signals including transcriptional control elements, polyadenylation signals and sequences needed for replication and integration of the viral genome. The viral LTR is divided into three regions called U3, R and U5.

The U3 region contains the enhancer and promoter elements. The U5 region contains the polyadenylation signals. The R (repeat) region separates the U3 and U5 regions and
20 transcribed sequences of the R region appear at both the 5' and 3' ends of the viral RNA.

The term "oligonucleotide" as used herein is defined as a molecule comprised of two or more deoxyribonucleotides or ribonucleotides, preferably at least 5 nucleotides, more preferably at least about 10-15 nucleotides and more preferably at least about 15 to 30 nucleotides. The exact size will depend on many factors, which in turn depends on the
25 ultimate function or use of the oligonucleotide. The oligonucleotide may be generated in any manner, including chemical synthesis, DNA replication, reverse transcription, or a combination thereof.

Because mononucleotides are reacted to make oligonucleotides in a manner such that the 5' phosphate of one mononucleotide pentose ring is attached to the 3' oxygen of its
30 neighbor in one direction via a phosphodiester linkage, an end of an oligonucleotide is referred to as the "5' end" if its 5' phosphate is not linked to the 3' oxygen of a mononucleotide pentose ring and as the "3' end" if its 3' oxygen is not linked to a 5' phosphate of a subsequent mononucleotide pentose ring. As used herein, a nucleic acid

sequence, even if internal to a larger oligonucleotide, also may be said to have 5' and 3' ends. A first region along a nucleic acid strand is said to be upstream of another region if the 3' end of the first region is before the 5' end of the second region when moving along a strand of nucleic acid in a 5' to 3' direction.

5 When two different, non-overlapping oligonucleotides anneal to different regions of the same linear complementary nucleic acid sequence, and the 3' end of one oligonucleotide points towards the 5' end of the other, the former may be called the "upstream" oligonucleotide and the latter the "downstream" oligonucleotide.

10 The term "primer" refers to an oligonucleotide which is capable of acting as a point of initiation of synthesis when placed under conditions in which primer extension is initiated. An oligonucleotide "primer" may occur naturally, as in a purified restriction digest or may be produced synthetically.

15 A primer is selected to be "substantially" complementary to a strand of specific sequence of the template. A primer must be sufficiently complementary to hybridize with a template strand for primer elongation to occur. A primer sequence need not reflect the exact sequence of the template. For example, a non-complementary nucleotide fragment may be attached to the 5' end of the primer, with the remainder of the primer sequence being substantially complementary to the strand. Non-complementary bases or longer sequences can be interspersed into the primer, provided that the primer sequence has sufficient
20 complementarity with the sequence of the template to hybridize and thereby form a template primer complex for synthesis of the extension product of the primer.

25 "Hybridization" methods involve the annealing of a complementary sequence to the target nucleic acid (the sequence to be detected: the detection of this sequence may be by either direct or indirect means). The ability of two polymers of nucleic acid containing complementary sequences to find each other and anneal through base pairing interaction is a well-recognized phenomenon. The initial observations of the "hybridization" process by Marmur and Lane, *Proc. Natl. Acad. Sci. USA* 46:453 (1960) and Doty *et al.*, *Proc. Natl. Acad. Sci. USA* 46:461 (1960) have been followed by the refinement of this process into an essential tool of modern biology.

30 With regard to complementarity, it is important for some diagnostic applications to determine whether the hybridization represents complete or partial complementarity. For example, where it is desired to detect simply the presence or absence of pathogen DNA (such as from a virus, bacterium, fungi, mycoplasma, protozoan) it is only important that the

hybridization method ensures hybridization when the relevant sequence is present; conditions can be selected where both partially complementary probes and completely complementary probes will hybridize. Other diagnostic applications, however, may require that the hybridization method distinguish between partial and complete complementarity. It may be of
5 interest to detect genetic polymorphisms. For example, human hemoglobin is composed, in part, of four polypeptide chains. Two of these chains are identical chains of 141 amino acids (alpha chains) and two of these chains are identical chains of 146 amino acids (beta chains). The gene encoding the beta chain is known to exhibit polymorphism. The normal allele encodes a beta chain having glutamic acid at the sixth position. The mutant allele encodes a
10 beta chain having valine at the sixth position. This difference in amino acids has a profound (most profound when the individual is homozygous for the mutant allele) physiological impact known clinically as sickle cell anemia. It is well known that the genetic basis of the amino acid change involves a single base difference between the normal allele DNA sequence and the mutant allele DNA sequence.

15 The complement of a nucleic acid sequence as used herein refers to an oligonucleotide which, when aligned with the nucleic acid sequence such that the 5' end of one sequence is paired with the 3' end of the other, is in "antiparallel association." Certain bases not commonly found in natural nucleic acids may be included in the nucleic acids of the present invention and include, for example, inosine and 7-deazaguanine. Complementarity need not
20 be perfect: stable duplexes may contain mismatched base pairs or unmatched bases. Those skilled in the art of nucleic acid technology can determine duplex stability empirically considering a number of variables including, for example, the length of the oligonucleotide, base composition and sequence of the oligonucleotide, ionic strength and incidence of mismatched base pairs.

25 Stability of a nucleic acid duplex is measured by the melting temperature, or " T_m ." The T_m of a particular nucleic acid duplex under specified conditions is the temperature at which on average half of the base pairs have disassociated.

The term "label" as used herein refers to any atom or molecule which can be used to provide a detectable (preferably quantifiable) signal, and which can be attached to a nucleic
30 acid or protein. Labels may provide signals detectable by fluorescence, radioactivity, colorimetry, gravimetry, X-ray diffraction or absorption, magnetism, enzymatic activity, and the like. A label may be a charged moiety (positive or negative charge) or alternatively, may be charge neutral.

The term "cleavage structure" as used herein, refers to a structure which is formed by the interaction of a probe oligonucleotide and a target nucleic acid to form a duplex, said resulting structure being cleavable by a cleavage means, including but not limited to an enzyme. The cleavage structure is a substrate for specific cleavage by said cleavage means in contrast to a nucleic acid molecule which is a substrate for non-specific cleavage by agents such as phosphodiesterases which cleave nucleic acid molecules without regard to secondary structure (*i.e.*, no formation of a duplexed structure is required).

The term "cleavage means" as used herein refers to any means which is capable of cleaving a cleavage structure, including but not limited to enzymes. The cleavage means may include native DNAPs having 5' nuclease activity (*e.g.*, *Taq* DNA polymerase, *E. coli* DNA polymerase I) and, more specifically, modified DNAPs having 5' nuclease but lacking synthetic activity. The ability of 5' nucleases to cleave naturally occurring structures in nucleic acid templates (structure-specific cleavage) is useful to detect internal sequence differences in nucleic acids without prior knowledge of the specific sequence of the nucleic acid. In this manner, they are structure-specific enzymes. "Structure-specific nucleases" or "structure-specific enzymes" are enzymes which recognize specific secondary structures in a nucleic molecule and cleave these structures. The cleavage means of the invention cleave a nucleic acid molecule in response to the formation of cleavage structures: it is not necessary that the cleavage means cleave the cleavage structure at any particular location within the cleavage structure.

The cleavage means is not restricted to enzymes having solely 5' nuclease activity. The cleavage means may include nuclease activity provided from a variety of sources including the Cleavase® enzymes, the FEN-1 endonucleases (including RAD2 and XPG proteins), *Taq* DNA polymerase and *E. coli* DNA polymerase I.

The term "thermostable" when used in reference to an enzyme, such as a 5' nuclease, indicates that the enzyme is functional or active (*i.e.*, can perform catalysis) at an elevated temperature, *i.e.*, at about 55°C or higher.

The term "cleavage products" as used herein, refers to products generated by the reaction of a cleavage means with a cleavage structure (*i.e.*, the treatment of a cleavage structure with a cleavage means).

The term "target nucleic acid" refers to a nucleic acid molecule which contains a sequence which has at least partial complementarity with at least a probe oligonucleotide and

may also have at least partial complementarity with an invader oligonucleotide. The target nucleic acid may comprise single- or double-stranded DNA or RNA.

5 The term "probe oligonucleotide" refers to an oligonucleotide which interacts with a target nucleic acid to form a cleavage structure in the presence or absence of an invader oligonucleotide. When annealed to the target nucleic acid, the probe oligonucleotide and target form a cleavage structure and cleavage occurs within the probe oligonucleotide. In the presence of an invader oligonucleotide upstream of the probe oligonucleotide along the target nucleic acid will shift the site of cleavage within the probe oligonucleotide (relative to the site of cleavage in the absence of the invader).

10 The term "non-target cleavage product" refers to a product of a cleavage reaction which is not derived from the target nucleic acid. As discussed above, in the methods of the present invention, cleavage of the cleavage structure occurs within the probe oligonucleotide. The fragments of the probe oligonucleotide generated by this target nucleic acid-dependent cleavage are "non-target cleavage products."

15 The term "invader oligonucleotide" refers to an oligonucleotide which contains sequences at its 3' end which are substantially the same as sequences located at the 5' end of a probe oligonucleotide; these regions will compete for hybridization to the same segment along a complementary target nucleic acid.

20 The term "substantially single-stranded" when used in reference to a nucleic acid substrate means that the substrate molecule exists primarily as a single strand of nucleic acid in contrast to a double-stranded substrate which exists as two strands of nucleic acid which are held together by inter-strand base pairing interactions.

25 The term "sequence variation" as used herein refers to differences in nucleic acid sequence between two nucleic acids. For example, a wild-type structural gene and a mutant form of this wild-type structural gene may vary in sequence by the presence of single base substitutions and/or deletions or insertions of one or more nucleotides. These two forms of the structural gene are said to vary in sequence from one another. A second mutant form of the structural gene may exist. This second mutant form is said to vary in sequence from both the wild-type gene and the first mutant form of the gene.

30 The term "liberating" as used herein refers to the release of a nucleic acid fragment from a larger nucleic acid fragment, such as an oligonucleotide, by the action of a 5' nuclease such that the released fragment is no longer covalently attached to the remainder of the oligonucleotide.

The term " K_m " as used herein refers to the Michaelis-Menten constant for an enzyme and is defined as the concentration of the specific substrate at which a given enzyme yields one-half its maximum velocity in an enzyme catalyzed reaction.

5 The term "nucleotide analog" as used herein refers to modified or non-naturally occurring nucleotides such as 7-deaza purines (*i.e.*, 7-deaza-dATP and 7-deaza-dGTP). Nucleotide analogs include base analogs and comprise modified forms of deoxyribonucleotides as well as ribonucleotides.

10 The term "polymorphic locus" is a locus present in a population which shows variation between members of the population (*i.e.*, the most common allele has a frequency of less than 0.95). In contrast, a "monomorphic locus" is a genetic locus at little or no variations seen between members of the population (generally taken to be a locus at which the most common allele exceeds a frequency of 0.95 in the gene pool of the population).

15 The term "microorganism" as used herein means an organism too small to be observed with the unaided eye and includes, but is not limited to bacteria, virus, protozoans, fungi, and ciliates.

The term "microbial gene sequences" refers to gene sequences derived from a microorganism.

The term "bacteria" refers to any bacterial species including eubacterial and archaeobacterial species.

20 The term "virus" refers to obligate, ultramicroscopic, intracellular parasites incapable of autonomous replication (*i.e.*, replication requires the use of the host cell's machinery).

The term "multi-drug resistant" or "multiple-drug resistant" refers to a microorganism which is resistant to more than one of the antibiotics or antimicrobial agents used in the treatment of said microorganism.

25 The term "sample" in the present specification and claims is used in its broadest sense. On the one hand it is meant to include a specimen or culture (*e.g.*, microbiological cultures). On the other hand, it is meant to include both biological and environmental samples.

30 Biological samples may be animal, including human, fluid, solid (*e.g.*, stool) or tissue, as well as liquid and solid food and feed products and ingredients such as dairy items, vegetables, meat and meat by-products, and waste. Biological samples may be obtained from all of the various families of domestic animals, as well as feral or wild animals, including, but not limited to, such animals as ungulates, bear, fish, lagamorphs, rodents, etc.

Environmental samples include environmental material such as surface matter, soil, water and industrial samples, as well as samples obtained from food and dairy processing instruments, apparatus, equipment, utensils, disposable and non-disposable items. These examples are not to be construed as limiting the sample types applicable to the present invention.

The term "source of target nucleic acid" refers to any sample which contains nucleic acids (RNA or DNA). Particularly preferred sources of target nucleic acids are biological samples including, but not limited to blood, saliva, cerebral spinal fluid, pleural fluid, milk, lymph, sputum and semen.

An oligonucleotide is said to be present in "excess" relative to another oligonucleotide (or target nucleic acid sequence) if that oligonucleotide is present at a higher molar concentration than the other oligonucleotide (or target nucleic acid sequence). When an oligonucleotide such as a probe oligonucleotide is present in a cleavage reaction in excess relative to the concentration of the complementary target nucleic acid sequence, the reaction may be used to indicate the amount of the target nucleic acid present. Typically, when present in excess, the probe oligonucleotide will be present at least a 100-fold molar excess; typically at least 1 pmole of each probe oligonucleotide would be used when the target nucleic acid sequence was present at about 10 fmoles or less.

A sample "suspected of containing" a first and a second target nucleic acid may contain either, both or neither target nucleic acid molecule.

The term "charge-balanced" oligonucleotide refers to an oligonucleotide (the input oligonucleotide in a reaction) which has been modified such that the modified oligonucleotide bears a charge, such that when the modified oligonucleotide is either cleaved (*i.e.*, shortened) or elongated, a resulting product bears a charge different from the input oligonucleotide (the "charge-unbalanced" oligonucleotide) thereby permitting separation of the input and reacted oligonucleotides on the basis of charge. The term "charge-balanced" does not imply that the modified or balanced oligonucleotide has a net neutral charge (although this can be the case). Charge-balancing refers to the design and modification of an oligonucleotide such that a specific reaction product generated from this input oligonucleotide can be separated on the basis of charge from the input oligonucleotide.

For example, in an invader-directed cleavage assay in which the probe oligonucleotide bears the sequence: 5'-TTCTTTTCACCAGCGAGACGGG-3' (*i.e.*, SEQ ID NO:50 without the modified bases) and cleavage of the probe occurs between the second and third residues,

one possible charge-balanced version of this oligonucleotide would be: 5'-Cy3-AminoT-Amino-TCTTTTACCAGCGAGAC GGG-3'. This modified oligonucleotide bears a net negative charge. After cleavage, the following oligonucleotides are generated: 5'-Cy3-AminoT-Amino-T-3' and 5'-CTTTTACCAGCGAGACGGG-3' (residues 3-22 of SEQ ID NO:50). 5'-Cy3-AminoT-Amino-T-3' bears a detectable moiety (the positively-charged Cy3 dye) and two amino-modified bases. The amino-modified bases and the Cy3 dye contribute positive charges in excess of the negative charges contributed by the phosphate groups and thus the 5'-Cy3-AminoT-Amino-T-3' oligonucleotide has a net positive charge. The other, longer cleavage fragment, like the input probe, bears a net negative charge. Because the 5'-Cy3-AminoT-Amino-T-3' fragment is separable on the basis of charge from the input probe (the charge-balanced oligonucleotide), it is referred to as a charge-unbalanced oligonucleotide. The longer cleavage product cannot be separated on the basis of charge from the input oligonucleotide as both oligonucleotides bear a net negative charge; thus, the longer cleavage product is not a charge-unbalanced oligonucleotide.

The term "net neutral charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (*i.e.* R-NH³⁺ groups on thymidines, the N3 nitrogen of cytosine, presence or absence of phosphate groups, etc.) under the desired reaction conditions is essentially zero. An oligonucleotide having a net neutral charge would not migrate in an electrical field.

The term "net positive charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (*i.e.* R-NH³⁺ groups on thymidines, the N3 nitrogen of cytosine, presence or absence of phosphate groups, etc.) under the desired reaction conditions is +1 or greater. An oligonucleotide having a net positive charge would migrate toward the negative electrode in an electrical field.

The term "net negative charge" when used in reference to an oligonucleotide, including modified oligonucleotides, indicates that the sum of the charges present (*i.e.* R-NH³⁺ groups on thymidines, the N3 nitrogen of cytosine, presence or absence of phosphate groups, etc.) under the desired reaction conditions is -1 or lower. An oligonucleotide having a net negative charge would migrate toward the positive electrode in an electrical field.

The term "polymerization means" refers to any agent capable of facilitating the addition of nucleoside triphosphates to an oligonucleotide. Preferred polymerization means comprise DNA polymerases.

The term "ligation means" refers to any agent capable of facilitating the ligation (*i.e.*, the formation of a phosphodiester bond between a 3'-OH and a 5'-P located at the termini of two strands of nucleic acid). Preferred ligation means comprise DNA ligases and RNA ligases.

5 The term "reactant" is used herein in its broadest sense. The reactant can comprise an enzymatic reactant, a chemical reactant or ultraviolet light (ultraviolet light, particularly short wavelength ultraviolet light is known to break oligonucleotide chains). Any agent capable of reacting with an oligonucleotide to either shorten (*i.e.*, cleave) or elongate the oligonucleotide is encompassed within the term "reactant."

10 The term "adduct" is used herein in its broadest sense to indicate any compound or element which can be added to an oligonucleotide. An adduct may be charged (positively or negatively) or may be charge neutral. An adduct may be added to the oligonucleotide via covalent or non-covalent linkages. Examples of adducts, include but are not limited to indodicarbocyanine dyes (*e.g.*, Cy3 and Cy5), amino-substituted nucleotides, ethidium
15 bromide, ethidium homodimer, (1,3-propanediamino)propidium, (diethylenetriamino)propidium, thiazole orange, (N-N'-tetramethyl-1,3-propanediamino)propyl thiazole orange, (N-N'-tetramethyl-1,2-ethanediamino)propyl thiazole orange, thiazole orange-thiazole orange homodimer (TOTO), thiazole orange-thiazole blue heterodimer (TOTAB), thiazole orange-ethidium heterodimer 1 (TOED1), thiazole orange-ethidium heterodimer 2
20 (TOED2) and florescien-ethidium heterodimer (FED), psoralens, biotin, streptavidin, avidin, etc.

Where a first oligonucleotide is complementary to a region of a target nucleic acid and a second oligonucleotide has complementary to the same region (or a portion of this region) a "region of overlap" exists along the target nucleic acid. The degree of overlap will vary
25 depending upon the nature of the complementarity (*see, e.g.*, region "X" in Figs. 25 and 56 and the accompanying discussions).

As used herein, the term "purified" or "to purify" refers to the removal of contaminants from a sample. For example, recombinant Cleavase® nucleases are expressed in bacterial host cells and the nucleases are purified by the removal of host cell proteins; the
30 percent of these recombinant nucleases is thereby increased in the sample.

The term "recombinant DNA molecule" as used herein refers to a DNA molecule which is comprised of segments of DNA joined together by means of molecular biological techniques.

The term "recombinant protein" or "recombinant polypeptide" as used herein refers to a protein molecule which is expressed from a recombinant DNA molecule.

As used herein the term "portion" when in reference to a protein (as in "a portion of a given protein") refers to fragments of that protein. The fragments may range in size from
5 four amino acid residues to the entire amino acid sequence minus one amino acid.

"Nucleic acid sequence" as used herein refers to an oligonucleotide, nucleotide or polynucleotide, and fragments or portions thereof, and to DNA or RNA of genomic or synthetic origin which may be single- or double-stranded, and represent the sense or antisense strand. Similarly, "amino acid sequence" as used herein refers to peptide or protein sequence.

10 "Peptide nucleic acid" ("PNA") as used herein refers to a molecule which comprises an oligomer to which an amino acid residue, such as lysine, and an amino group have been added. These small molecules, also designated anti-gene agents, stop transcript elongation by binding to their complementary strand of nucleic acid [Nielsen PE *et al.* (1993) *Anticancer Drug Des.* 8:53-63].

15 As used herein, the terms "purified" or "substantially purified" refer to molecules, either nucleic or amino acid sequences, that are removed from their natural environment, isolated or separated, and are at least 60% free, preferably 75% free, and most preferably 90% free from other components with which they are naturally associated. An "isolated polynucleotide" or "isolated oligonucleotide" is therefore a substantially purified
20 polynucleotide.

An isolated oligonucleotide (or polynucleotide) encoding a *Pyrococcus woesei* (*Pwo*) FEN-1 endonuclease having a region capable of hybridizing to SEQ ID NO:80 is an oligonucleotide containing sequences encoding at least the amino-terminal portion of *Pwo* FEN-1 endonuclease. An isolated oligonucleotide (or polynucleotide) encoding a *Pwo* FEN-1
25 endonuclease having a region capable of hybridizing to SEQ ID NO:81 is an oligonucleotide containing sequences encoding at least the carboxy-terminal portion of *Pwo* FEN-1 endonuclease. An isolated oligonucleotide (or polynucleotide) encoding a *Pwo* FEN-1 endonuclease having a region capable of hybridizing to SEQ ID NOS:82 and 83 is an oligonucleotide containing sequences encoding at least portions of *Pwo* FEN-1 endonuclease
30 protein located internal to either the amino or carboxy-termini of the *Pwo* FEN-1 endonuclease protein.

As used herein, the term "fusion protein" refers to a chimeric protein containing the protein of interest (*i.e.*, Cleavase® BN/thrombin nuclease and portions or fragments thereof)

joined to an exogenous protein fragment (the fusion partner which consists of a non-Cleavase® BN/thrombin nuclease protein). The fusion partner may enhance solubility of recombinant chimeric protein (e.g., the Cleavase® BN/thrombin nuclease) as expressed in a host cell. may provide an affinity tag (e.g., a his-tag) to allow purification of the recombinant fusion protein from the host cell or culture supernatant, or both. If desired, the fusion protein may be removed from the protein of interest (e.g., Cleavase® BN/thrombin nuclease or fragments thereof) by a variety of enzymatic or chemical means known to the art.

The term "purified *Pfu* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons" refers to a FEN-1 endonuclease isolated from *Pyrococcus woesei* which has a molecular weight on SDS-PAGE gels of about 38.7 kDa when the SDS-PAGE is conducted under the conditions described in Ex. 28. Those skilled in the art understand that the same protein preparation applied to separate gels of apparently the same composition can yield estimated molecular weights which vary somewhat from one another (approximately 5-15%).

The term "continuous strand of nucleic acid" as used herein is means a strand of nucleic acid that has a continuous, covalently linked, backbone structure, without nicks or other disruptions. The disposition of the base portion of each nucleotide, whether base-paired, single-stranded or mismatched, is not an element in the definition of a continuous strand. The backbone of the continuous strand is not limited to the ribose-phosphate or deoxyribose-phosphate compositions that are found in naturally occurring, unmodified nucleic acids. A nucleic acid of the present invention may comprise modifications in the structure of the backbone, including but not limited to phosphorothioate residues, phosphonate residues, 2' substituted ribose residues (e.g., 2'-O-methyl ribose) and alternative sugar (e.g., arabinose) containing residues.

The term "continuous duplex" as used herein refers to a region of double stranded nucleic acid in which there is no disruption in the progression of basepairs within the duplex, i.e., the base pairs along the duplex are not distorted to accommodate a gap, bulge or mismatch with the confines of the region of continuous duplex. As used herein the term refers only to the arrangement of the basepairs within the duplex, without implication of continuity in the backbone portion of the nucleic acid strand. Duplex nucleic acids with uninterrupted basepairing, but with nicks in one or both strands are within the definition of a continuous duplex.

The term "duplex" refers to the state of nucleic acids in which the base portions of the nucleotides on one strand are bound through hydrogen bonding the their complementary bases

arrayed on a second strand. The condition of being in a duplex form reflects on the state of the bases of a nucleic acid. By virtue of base pairing, the strands of nucleic acid also generally assume the tertiary structure of a double helix, having a major and a minor groove. The assumption of the helical form is implicit in the act of becoming duplexed.

5 The term "duplex dependent protein binding" refers to the binding of proteins to nucleic acid that is dependent on the nucleic acid being in a duplex, or helical form.

 The term "duplex dependent protein binding sites or regions" as used herein refers to discrete regions or sequences within a nucleic acid that are bound with particular affinity by specific duplex-dependent nucleic acid binding proteins. This is in contrast to the generalized
10 duplex-dependent binding of proteins that are not site-specific, such as the histone proteins that bind chromatin with little reference to specific sequences or sites.

 The term "protein binding region" as used herein refers to a nucleic acid region identified by a sequence or structure as binding to a particular protein or class of proteins. It is within the scope of this definition to include those regions that contain sufficient genetic
15 information to allow identifications of the region by comparison to known sequences, but which might not have the requisite structure for actual binding (*e.g.*, a single strand of a duplex-dependent nucleic acid binding protein site). As used herein "protein binding region" excludes restriction endonuclease binding regions.

 The term "complete double stranded protein binding region" as used herein refers to
20 the minimum region of continuous duplex required to allow binding or other activity of a duplex-dependent protein. This definition is intended to encompass the observation that some duplex dependent nucleic acid binding proteins can interact with full activity with regions of duplex that may be shorter than a canonical protein binding region as observed in one or the other of the two single strands. In other words, one or more nucleotides in the region may be
25 allowed to remain unpaired without suppressing binding. As used here in, the term "complete double stranded binding region" refers to the minimum sequence that will accommodate the binding function. Because some such regions can tolerate non-duplex sequences in multiple places, although not necessarily simultaneously, a single protein binding region might have several shorter sub-regions that, when duplexed, will be fully competent for protein binding.

30 The term "template" refers to a strand of nucleic acid on which a complementary copy is built from nucleoside triphosphates through the activity of a template-dependent nucleic acid polymerase. Within a duplex the template strand is, by convention, depicted and

described as the "bottom" strand. Similarly, the non-template strand is often depicted and described as the "top" strand.

The term "template-dependent RNA polymerase" refers to a nucleic acid polymerase that creates new RNA strands through the copying of a template strand as described above and which does not synthesize RNA in the absence of a template. This is in contrast to the activity of the template-independent nucleic acid polymerases that synthesize or extend nucleic acids without reference to a template, such as terminal deoxynucleotidyl transferase, or Poly A polymerase.

DESCRIPTION OF THE INVENTION

The present invention relates to methods and compositions for treating nucleic acid, and in particular, methods and compositions for detection and characterization of nucleic acid sequences and sequence changes.

The present invention relates to means for cleaving a nucleic acid cleavage structure in a site-specific manner. In particular, the present invention relates to a cleaving enzyme having 5' nuclease activity without interfering nucleic acid synthetic ability.

This invention provides 5' nucleases derived from thermostable DNA polymerases which exhibit altered DNA synthetic activity from that of native thermostable DNA polymerases. The 5' nuclease activity of the polymerase is retained while the synthetic activity is reduced or absent. Such 5' nucleases are capable of catalyzing the structure-specific cleavage of nucleic acids in the absence of interfering synthetic activity. The lack of synthetic activity during a cleavage reaction results in nucleic acid cleavage products of uniform size.

The novel properties of the nucleases of the invention form the basis of a method of detecting specific nucleic acid sequences. This method relies upon the amplification of the detection molecule rather than upon the amplification of the target sequence itself as do existing methods of detecting specific target sequences.

DNA polymerases (DNAPs), such as those isolated from *E. coli* or from thermophilic bacteria of the genus *Thermus*, are enzymes that synthesize new DNA strands. Several of the known DNAPs contain associated nuclease activities in addition to the synthetic activity of the enzyme.

Some DNAPs are known to remove nucleotides from the 5' and 3' ends of DNA chains [Kornberg, *DNA Replication*, W.H. Freeman and Co., San Francisco, pp. 127-139

(1980)). These nuclease activities are usually referred to as 5' exonuclease and 3' exonuclease activities, respectively. For example, the 5' exonuclease activity located in the N-terminal domain of several DNAPs participates in the removal of RNA primers during lagging strand synthesis during DNA replication and the removal of damaged nucleotides during repair. Some DNAPs, such as the *E. coli* DNA polymerase (DNAPEc1), also have a 3' exonuclease activity responsible for proof-reading during DNA synthesis (Kornberg, *supra*).

A DNAP isolated from *Thermus aquaticus*, termed *Taq* DNA polymerase (DNAPTaq), has a 5' exonuclease activity, but lacks a functional 3' exonucleolytic domain [Tindall and Kunkell, *Biochem.* 27:6008 (1988)]. Derivatives of DNAPEc1 and DNAPTaq, respectively called the Klenow and Stoffel fragments, lack 5' exonuclease domains as a result of enzymatic or genetic manipulations [Brutlag *et al.*, *Biochem. Biophys. Res. Commun.* 37:982 (1969); Erlich *et al.*, *Science* 252:1643 (1991); Setlow and Kornberg, *J. Biol. Chem.* 247:232 (1972)].

The 5' exonuclease activity of DNAPTaq was reported to require concurrent synthesis [Gelfand, *PCR Technology - Principles and Applications for DNA Amplification* (H.A. Erlich, Ed.), Stockton Press, New York, p. 19 (1989)]. Although mononucleotides predominate among the digestion products of the 5' exonucleases of DNAPTaq and DNAPEc1, short oligonucleotides (≤ 12 nucleotides) can also be observed implying that these so-called 5' exonucleases can function endonucleolytically [Setlow, *supra*; Holland *et al.*, *Proc. Natl. Acad. Sci. USA* 88:7276 (1991)].

In WO 92/06200, Gelfand *et al.* show that the preferred substrate of the 5' exonuclease activity of the thermostable DNA polymerases is displaced single-stranded DNA. Hydrolysis of the phosphodiester bond occurs between the displaced single-stranded DNA and the double-helical DNA with the preferred exonuclease cleavage site being a phosphodiester bond in the double helical region. Thus, the 5' exonuclease activity usually associated with DNAPs is a structure-dependent single-stranded endonuclease and is more properly referred to as a 5' nuclease. Exonucleases are enzymes which cleave nucleotide molecules from the ends of the nucleic acid molecule. Endonucleases, on the other hand, are enzymes which cleave the nucleic acid molecule at internal rather than terminal sites. The nuclease activity associated with some thermostable DNA polymerases cleaves endonucleolytically but this cleavage requires contact with the 5' end of the molecule being cleaved. Therefore, these nucleases are referred to as 5' nucleases.

When a 5' nuclease activity is associated with a eubacterial Type A DNA polymerase, it is found in the one-third N-terminal region of the protein as an independent functional domain. The C-terminal two-thirds of the molecule constitute the polymerization domain which is responsible for the synthesis of DNA. Some Type A DNA polymerases also have a 3' exonuclease activity associated with the two-third C-terminal region of the molecule.

The 5' exonuclease activity and the polymerization activity of DNAPs have been separated by proteolytic cleavage or genetic manipulation of the polymerase molecule. To date thermostable DNAPs have been modified to remove or reduce the amount of 5' nuclease activity while leaving the polymerase activity intact.

The Klenow or large proteolytic cleavage fragment of DNAPEcI contains the polymerase and 3' exonuclease activity but lacks the 5' nuclease activity. The Stoffel fragment of DNAP_{Taq} (DNAPStf) lacks the 5' nuclease activity due to a genetic manipulation which deleted the N-terminal 289 amino acids of the polymerase molecule [Erllich *et al.*, *Science* 252:1643 (1991)]. WO 92/06200 describes a thermostable DNAP with an altered level of 5' to 3' exonuclease. U.S. Patent No. 5,108,892 describes a *Thermus aquaticus* DNAP without a 5' to 3' exonuclease. However, the art of molecular biology lacks a thermostable DNA polymerase with a lessened amount of synthetic activity.

The present invention provides 5' nucleases derived from thermostable Type A DNA polymerases that retain 5' nuclease activity but have reduced or absent synthetic activity. The ability to uncouple the synthetic activity of the enzyme from the 5' nuclease activity proves that the 5' nuclease activity does not require concurrent DNA synthesis as was previously reported (Gelfand, *PCR Technology, supra*).

The description of the invention is divided into: I. Generation of 5' Nucleases Derived From Thermostable DNA Polymerases; II. Detection of Specific Nucleic Acid Sequences Using 5' Nucleases in an Invader-Directed Cleavage Assay; III. A Comparison Of Invasive Cleavage And Primer-Directed Cleavage; IV. Fractionation Of Specific Nucleic Acids By Selective Charge Reversal; V. InvaderTM-Directed Cleavage Using Miniprobcs And Mid-Range Probes; VI. Signal Enhancement By Tailing Of Reaction Products In The InvaderTM-Directed Cleavage Assay; and VII. Improved Enzymes For Use In InvaderTM-Directed Cleavage Reactions.

I. Generation Of 5' Nucleases From Thermostable DNA Polymerases

The genes encoding Type A DNA polymerases share about 85% homology to each other on the DNA sequence level. Preferred examples of thermostable polymerases include those isolated from *Thermus aquaticus*, *Thermus flavus*, and *Thermus thermophilus*. However, other thermostable Type A polymerases which have 5' nuclease activity are also suitable. Figs. 1 and 2 compare the nucleotide and amino acid sequences of the three above mentioned polymerases. In Figs. 1 and 2, the consensus or majority sequence derived from a comparison of the nucleotide (Fig. 1) or amino acid (Fig. 2) sequence of the three thermostable DNA polymerases is shown on the top line. A dot appears in the sequences of each of these three polymerases whenever an amino acid residue in a given sequence is identical to that contained in the consensus amino acid sequence. Dashes are used to introduce gaps in order to maximize alignment between the displayed sequences. When no consensus nucleotide or amino acid is present at a given position, an "X" is placed in the consensus sequence. SEQ ID NOS:1-3 display the nucleotide sequences and SEQ ID NOS:4-6 display the amino acid sequences of the three wild-type polymerases. SEQ ID NO:1 corresponds to the nucleic acid sequence of the wild type *Thermus aquaticus* DNA polymerase gene isolated from the YT-1 strain [Lawyer *et al.*, *J. Biol. Chem.* 264:6427 (1989)]. SEQ ID NO:2 corresponds to the nucleic acid sequence of the wild type *Thermus flavus* DNA polymerase gene [Akhmetzjanov and Vakhitov, *Nucl. Acids Res.* 20:5839 (1992)]. SEQ ID NO:3 corresponds to the nucleic acid sequence of the wild type *Thermus thermophilus* DNA polymerase gene [Gelfand *et al.*, WO 91/09950 (1991)]. SEQ ID NOS:7-8 depict the consensus nucleotide and amino acid sequences, respectively for the above three DNAPs (also shown on the top row in Figs. 2 and 3).

The 5' nucleases of the invention derived from thermostable polymerases have reduced synthetic ability, but retain substantially the same 5' exonuclease activity as the native DNA polymerase. The term "substantially the same 5' nuclease activity" as used herein means that the 5' nuclease activity of the modified enzyme retains the ability to function as a structure-dependent single-stranded endonuclease but not necessarily at the same rate of cleavage as compared to the unmodified enzyme. Type A DNA polymerases may also be modified so as to produce an enzyme which has increases 5' nuclease activity while having a reduced level of synthetic activity. Modified enzymes having reduced synthetic activity and increased 5' nuclease activity are also envisioned by the present invention.

By the term "reduced synthetic activity" as used herein it is meant that the modified enzyme has less than the level of synthetic activity found in the unmodified or "native" enzyme. The modified enzyme may have no synthetic activity remaining or may have that level of synthetic activity that will not interfere with the use of the modified enzyme in the detection assay described below. The 5' nucleases of the present invention are advantageous in situations where the cleavage activity of the polymerase is desired, but the synthetic ability is not (such as in the detection assay of the invention).

As noted above, it is not intended that the invention be limited by the nature of the alteration necessary to render the polymerase synthesis deficient. The present invention contemplates a variety of methods, including but not limited to: 1) proteolysis; 2) recombinant constructs (including mutants); and 3) physical and/or chemical modification and/or inhibition.

1. Proteolysis

Thermostable DNA polymerases having a reduced level of synthetic activity are produced by physically cleaving the unmodified enzyme with proteolytic enzymes to produce fragments of the enzyme that are deficient in synthetic activity but retain 5' nuclease activity. Following proteolytic digestion, the resulting fragments are separated by standard chromatographic techniques and assayed for the ability to synthesize DNA and to act as a 5' nuclease. The assays to determine synthetic activity and 5' nuclease activity are described below.

2. Recombinant Constructs

The examples below describe a preferred method for creating a construct encoding a 5' nuclease derived from a thermostable DNA polymerase. As the Type A DNA polymerases are similar in DNA sequence, the cloning strategies employed for the *Thermus aquaticus* and *flavus* polymerases are applicable to other thermostable Type A polymerases. In general, a thermostable DNA polymerase is cloned by isolating genomic DNA using molecular biological methods from a bacteria containing a thermostable Type A DNA polymerase. This genomic DNA is exposed to primers which are capable of amplifying the polymerase gene by PCR.

This amplified polymerase sequence is then subjected to standard deletion processes to delete the polymerase portion of the gene. Suitable deletion processes are described below in the examples.

5 The example below discusses the strategy used to determine which portions of the DNAP*Taq* polymerase domain could be removed without eliminating the 5' nuclease activity. Deletion of amino acids from the protein can be done either by deletion of the encoding genetic material, or by introduction of a translational stop codon by mutation or frame shift. In addition, proteolytic treatment of the protein molecule can be performed to remove segments of the protein.

10 In the examples below, specific alterations of the *Taq* gene were: a deletion between nucleotides 1601 and 2502 (the end of the coding region), a 4 nucleotide insertion at position 2043, and deletions between nucleotides 1614 and 1848 and between nucleotides 875 and 1778 (numbering is as in SEQ ID NO:1). These modified sequences are described below in the examples and at SEQ ID NOS:9-12.

15 Those skilled in the art understand that single base pair changes can be innocuous in terms of enzyme structure and function. Similarly, small additions and deletions can be present without substantially changing the exonuclease or polymerase function of these enzymes.

20 Other deletions are also suitable to create the 5' nucleases of the present invention. It is preferable that the deletion decrease the polymerase activity of the 5' nucleases to a level at which synthetic activity will not interfere with the use of the 5' nuclease in the detection assay of the invention. Most preferably, the synthetic ability is absent. Modified polymerases are tested for the presence of synthetic and 5' nuclease activity as in assays described below. Thoughtful consideration of these assays allows for the screening of candidate enzymes whose structure is heretofore as yet unknown. In other words, construct "X" can be evaluated according to the protocol described below to determine whether it is a member of the genus of 5' nucleases of the present invention as defined functionally, rather than structurally.

25 In the example below, the PCR product of the amplified *Thermus aquaticus* genomic DNA did not have the identical nucleotide structure of the native genomic DNA and did not have the same synthetic ability of the original clone. Base pair changes which result due to the infidelity of DNAP*Taq* during PCR amplification of a polymerase gene are also a method by which the synthetic ability of a polymerase gene may be inactivated. The examples below and Figs. 3A and 4A indicate regions in the native *Thermus aquaticus* and *flavus* DNA

polymerases likely to be important for synthetic ability. There are other base pair changes and substitutions that will likely also inactivate the polymerase.

It is not necessary, however, that one start out the process of producing a 5' nuclease from a DNA polymerase with such a mutated amplified product. This is the method by which the examples below were performed to generate the synthesis-deficient DNAP_{Taq} mutants. but it is understood by those skilled in the art that a wild-type DNA polymerase sequence may be used as the starting material for the introduction of deletions, insertion and substitutions to produce a 5' nuclease. For example, to generate the synthesis-deficient DNAP_{Tfl} mutant, the primers listed in SEQ ID NOS:13-14 were used to amplify the wild type DNA polymerase gene from *Thermus flavus* strain AT-62. The amplified polymerase gene was then subjected to restriction enzyme digestion to delete a large portion of the domain encoding the synthetic activity.

The present invention contemplates that the nucleic acid construct of the present invention be capable of expression in a suitable host. Those in the art know methods for attaching various promoters and 3' sequences to a gene structure to achieve efficient expression. The examples below disclose two suitable vectors and six suitable vector constructs. Of course, there are other promoter/vector combinations that would be suitable. It is not necessary that a host organism be used for the expression of the nucleic acid constructs of the invention. For example, expression of the protein encoded by a nucleic acid construct may be achieved through the use of a cell-free in vitro transcription/translation system. An example of such a cell-free system is the commercially available TnTTM Coupled Reticulocyte Lysate System (Promega Corporation, Madison, WI).

Once a suitable nucleic acid construct has been made, the 5' nuclease may be produced from the construct. The examples below and standard molecular biological teachings enable one to manipulate the construct by different suitable methods.

Once the 5' nuclease has been expressed, the polymerase is tested for both synthetic and nuclease activity as described below.

3. Physical And/Or Chemical Modification And/Or Inhibition

The synthetic activity of a thermostable DNA polymerase may be reduced by chemical and/or physical means. In one embodiment, the cleavage reaction catalyzed by the 5' nuclease activity of the polymerase is run under conditions which preferentially inhibit the synthetic activity of the polymerase. The level of synthetic activity need only be reduced to

that level of activity which does not interfere with cleavage reactions requiring no significant synthetic activity.

As shown in the examples below, concentrations of Mg^{++} greater than 5 mM inhibit the polymerization activity of the native DNAP Taq . The ability of the 5' nuclease to function under conditions where synthetic activity is inhibited is tested by running the assays for synthetic and 5' nuclease activity, described below, in the presence of a range of Mg^{++} concentrations (5 to 10 mM). The effect of a given concentration of Mg^{++} is determined by quantitation of the amount of synthesis and cleavage in the test reaction as compared to the standard reaction for each assay.

The inhibitory effect of other ions, polyamines, denaturants, such as urea, formamide, dimethylsulfoxide, glycerol and non-ionic detergents (Triton X-100 and Tween-20), nucleic acid binding chemicals such as, actinomycin D, ethidium bromide and psoralens, are tested by their addition to the standard reaction buffers for the synthesis and 5' nuclease assays. Those compounds having a preferential inhibitory effect on the synthetic activity of a thermostable polymerase are then used to create reaction conditions under which 5' nuclease activity (cleavage) is retained while synthetic activity is reduced or eliminated.

Physical means may be used to preferentially inhibit the synthetic activity of a polymerase. For example, the synthetic activity of thermostable polymerases is destroyed by exposure of the polymerase to extreme heat (typically 96 to 100°C) for extended periods of time (greater than or equal to 20 minutes). While these are minor differences with respect to the specific heat tolerance for each of the enzymes, these are readily determined. Polymerases are treated with heat for various periods of time and the effect of the heat treatment upon the synthetic and 5' nuclease activities is determined.

II. Detection Of Specific Nucleic Acid Sequences Using 5' Nucleases In An Invader-Directed Cleavage Assay

The present invention provides means for forming a nucleic acid cleavage structure which is dependent upon the presence of a target nucleic acid and cleaving the nucleic acid cleavage structure so as to release distinctive cleavage products. 5' nuclease activity is used to cleave the target-dependent cleavage structure and the resulting cleavage products are indicative of the presence of specific target nucleic acid sequences in the sample.

The present invention further provides assays in which the target nucleic acid is reused or recycled during multiple rounds of hybridization with oligonucleotide probes and cleavage

without the need to use temperature cycling (*i.e.*, for periodic denaturation of target nucleic acid strands) or nucleic acid synthesis (*i.e.*, for the displacement of target nucleic acid strands). Through the interaction of the cleavage means (*e.g.*, a 5' nuclease) an upstream oligonucleotide, the cleavage means can be made to cleave a downstream oligonucleotide at an internal site in such a way that the resulting fragments of the downstream oligonucleotide dissociate from the target nucleic acid, thereby making that region of the target nucleic acid available for hybridization to another, uncleaved copy of the downstream oligonucleotide.

As illustrated in Fig. 25, the methods of the present invention employ at least a pair of oligonucleotides that interact with a target nucleic acid to form a cleavage structure for a structure-specific nuclease. More specifically, the cleavage structure comprises: i) a target nucleic acid that may be either single-stranded or double-stranded (when a double-stranded target nucleic acid is employed, it may be rendered single stranded, *e.g.*, by heating); ii) a first oligonucleotide, termed the "probe," which defines a first region of the target nucleic acid sequence by being the complement of that region (regions X and Z of the target as shown in Fig. 25); and iii) a second oligonucleotide, termed the "invader," the 5' part of which defines a second region of the same target nucleic acid sequence (regions Y and X in Fig. 25), adjacent to and downstream of the first target region (regions X and Z), and the second part of which overlaps into the region defined by the first oligonucleotide (region X depicts the region of overlap). The resulting structure is diagrammed in Fig. 25.

While not limiting the invention or the instant discussion to any particular mechanism of action, the diagram in Fig. 25 represents the effect on the site of cleavage caused by this type of arrangement of a pair of oligonucleotides. The design of such a pair of oligonucleotides is described below in detail. In Fig. 25, the 3' ends of the nucleic acids (*i.e.*, the target and the oligonucleotides) are indicated by the use of the arrowheads on the ends of the lines depicting the strands of the nucleic acids (and where space permits, these ends are also labelled "3'"). It is readily appreciated that the two oligonucleotides (the invader and the probe) are arranged in a parallel orientation relative to one another, while the target nucleic acid strand is arranged in an anti-parallel orientation relative to the two oligonucleotides. Further it is clear that the invader oligonucleotide is located upstream of the probe oligonucleotide and that with respect to the target nucleic acid strand, region Z is upstream of region X and region X is upstream of region Y (that is region Y is downstream of region X and region X is downstream of region Z). Regions of complementarity between the opposing strands are indicated by the short vertical lines. While not intended to indicate the precise

location of the site(s) of cleavage, the area to which the site of cleavage within the probe oligonucleotide is shifted by the presence of the invader oligonucleotide is indicated by the solid vertical arrowhead. An alternative representation of the target/invader/probe cleavage structure is shown in Fig. 28C. Neither diagram (*i.e.*, Fig. 25 or Fig. 28C) is intended to
5 represent the actual mechanism of action or physical arrangement of the cleavage structure and further it is not intended that the method of the present invention be limited to any particular mechanism of action.

It can be considered that the binding of these oligonucleotides divides the target nucleic acid into three distinct regions: one region that has complementarity to only the probe
10 (shown as "Z"); one region that has complementarity only to the invader (shown as "Y"); and one region that has complementarity to both oligonucleotides (shown as "X").

Design of these oligonucleotides (*i.e.*, the invader and the probe) is accomplished using practices which are standard in the art. For example, sequences that have self
complementarity, such that the resulting oligonucleotides would either fold upon themselves,
15 or hybridize to each other at the expense of binding to the target nucleic acid, are generally avoided.

One consideration in choosing a length for these oligonucleotides is the complexity of the sample containing the target nucleic acid. For example, the human genome is
approximately 3×10^9 basepairs in length. Any 10 nucleotide sequence will appear with a
20 frequency of $1:4^{10}$, or 1:1048,576 in a random string of nucleotides, which would be approximately 2.861 times in 3 billion basepairs. Clearly an oligonucleotide of this length would have a poor chance of binding uniquely to a 10 nucleotide region within a target
having a sequence the size of the human genome. If the target sequence were within a 3 kb plasmid, however, such an oligonucleotide might have a very reasonable chance of binding
25 uniquely. By this same calculation it can be seen that an oligonucleotide of 16 nucleotides (*i.e.*, a 16-mer) is the minimum length of a sequence which is mathematically likely to appear once in 3×10^9 basepairs.

A second consideration in choosing oligonucleotide length is the temperature range in which the oligonucleotides will be expected to function. A 16-mer of average base content
30 (50% G-C basepairs) will have a calculated T_m (the temperature at which 50% of the sequence is dissociated) of about 41°C, depending on, among other things, the concentration of the oligonucleotide and its target, the salt content of the reaction and the precise order of the nucleotides. As a practical matter, longer oligonucleotides are usually chosen to enhance

the specificity of hybridization. Oligonucleotides 20 to 25 nucleotides in length are often used as they are highly likely to be specific if used in reactions conducted at temperatures which are near their T_m s (within about 5° of the T_m). In addition, with calculated T_m s in the range of 50° to 70°C, such oligonucleotides (*i.e.* 20 to 25-mers) are appropriately used in reactions catalyzed by thermostable enzymes, which often display optimal activity near this temperature range.

The maximum length of the oligonucleotide chosen is also based on the desired specificity. One must avoid choosing sequences that are so long that they are either at a high risk of binding stably to partial complements, or that they cannot easily be dislodged when desired (*e.g.*, failure to disassociate from the target once cleavage has occurred).

The first step of design and selection of the oligonucleotides for the invader-directed cleavage is in accordance with these sample general principles. Considered as sequence-specific probes individually, each oligonucleotide may be selected according to the guidelines listed above. That is to say, each oligonucleotide will generally be long enough to be reasonably expected to hybridize only to the intended target sequence within a complex sample, usually in the 20 to 40 nucleotide range. Alternatively, because the invader-directed cleavage assay depends upon the concerted action of these oligonucleotides, the composite length of the 2 oligonucleotides which span/bind to the X, Y, Z regions may be selected to fall within this range, with each of the individual oligonucleotides being in approximately the 13 to 17 nucleotide range. Such a design might be employed if a non-thermostable cleavage means were employed in the reaction, requiring the reactions to be conducted at a lower temperature than that used when thermostable cleavage means are employed. In some instances, it may be desirable to have these oligonucleotides bind multiple times within a target nucleic acid (*e.g.*, which bind to multiple variants or multiple similar sequences within a target). It is not intended that the method of the present invention be limited to any particular size of the probe or invader oligonucleotide.

The second step of designing an oligonucleotide pair for this assay is to choose the degree to which the upstream "invader" oligonucleotide sequence will overlap into the downstream "probe" oligonucleotide sequence, and consequently, the sizes into which the probe will be cleaved. A key feature of this assay is that the probe oligonucleotide can be made to "turn over," that is to say cleaved probe can be made to depart to allow the binding and cleavage of other copies of the probe molecule, without the requirements of thermal denaturation or displacement by polymerization. While in one embodiment of this assay

probe turnover may be facilitated by an exonucleolytic digestion by the cleavage agent, it is central to the present invention that the turnover does not require this exonucleolytic activity.

Choosing The Amount Of Overlap (Length Of The X Region)

5 One way of accomplishing such turnover can be envisioned by considering the diagram in Fig. 25. It can be seen that the T_m of each oligonucleotide will be a function of the full length of that oligonucleotide: *i.e.*, the T_m of the invader = $T_{m(Y+X)}$, and the T_m of the probe = $T_{m(X+Y)}$ for the probe. When the probe is cleaved the X region is released, leaving the Z section. If the T_m of Z is less than the reaction temperature, and the reaction temperature is less than the $T_{m(X+Z)}$, then cleavage of the probe will lead to the departure of Z, thus allowing
10 a new (X+Z) to hybridize. It can be seen from this example that the X region must be sufficiently long that the release of X will drop the T_m of the remaining probe section below the reaction temperature: a G-C rich X section may be much shorter than an A-T rich X section and still accomplish this stability shift.

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Designing Oligonucleotides Which Interact With The Y And Z Regions

If the binding of the invader oligonucleotide to the target is more stable than the binding of the probe (*e.g.*, if it is long, or is rich in G-C basepairs in the Y region), then the copy of X associated with the invader may be favored in the competition for binding to the X region of the target, and the probe may consequently hybridize inefficiently, and the assay
20 may give low signal. Alternatively, if the probe binding is particularly strong in the Z region, the invader will still cause internal cleavage, because this is mediated by the enzyme, but portion of the probe oligonucleotide bound to the Z region may not dissociate at the reaction temperature, turnover may be poor, and the assay may again give low signal.

25 It is clearly beneficial for the portions of the oligonucleotide which interact with the Y and Z regions so be similar in stability, *i.e.*, they must have similar melting temperatures. This is not to say that these regions must be the same length. As noted above, in addition to length, the melting temperature will also be affected by the base content and the specific sequence of those bases. The specific stability designed into the invader and probe sequences
30 will depend on the temperature at which one desires to perform the reaction.

This discussion is intended to illustrate that (within the basic guidelines for oligonucleotide specificity discussed above) it is the balance achieved between the stabilities of the probe and invader sequences and their X and Y component sequences, rather than the

absolute values of these stabilities, that is the chief consideration in the selection of the probe and invader sequences.

Design Of The Reaction Conditions

5 Target nucleic acids that may be analyzed using the methods of the present invention which employ a 5' nuclease as the cleavage means include many types of both RNA and DNA. Such nucleic acids may be obtained using standard molecular biological techniques. For example, nucleic acids (RNA or DNA) may be isolated from a tissue sample (e.g., a biopsy specimen), tissue culture cells, samples containing bacteria and/or viruses (including
10 cultures of bacteria and/or viruses), etc. The target nucleic acid may also be transcribed *in vitro* from a DNA template or may be chemically synthesized or generated in a PCR. Furthermore, nucleic acids may be isolated from an organism, either as genomic material or as a plasmid or similar extrachromosomal DNA, or they may be a fragment of such material generated by treatment with a restriction endonuclease or other cleavage agents or it may be
15 synthetic.

Assembly of the target, probe, and invader nucleic acids into the cleavage reaction of the present invention uses principles commonly used in the design of oligonucleotide base enzymatic assays, such as dideoxynucleotide sequencing and polymerase chain reaction (PCR). As is done in these assays, the oligonucleotides are provided in sufficient excess that the rate
20 of hybridization to the target nucleic acid is very rapid. These assays are commonly performed with 50 fmoles to 2 pmoles of each oligonucleotide per μ l of reaction mixture. In the Examples described herein, amounts of oligonucleotides ranging from 250 fmoles to 5 pmoles per μ l of reaction volume were used. These values were chosen for the purpose of ease in demonstration and are not intended to limit the performance of the present invention
25 to these concentrations. Other (e.g., lower) oligonucleotide concentrations commonly used in other molecular biological reactions are also contemplated.

It is desirable that an invader oligonucleotide be immediately available to direct the cleavage of each probe oligonucleotide that hybridizes to a target nucleic acid. For this reason, in the Examples described herein, the invader oligonucleotide is provided in excess
30 over the probe oligonucleotide; often this excess is 10-fold. While this is an effective ratio, it is not intended that the practice of the present invention be limited to any particular ratio of invader-to-probe (a ratio of 2- to 100-fold is contemplated).

Buffer conditions must be chosen that will be compatible with both the oligonucleotide/target hybridization and with the activity of the cleavage agent. The optimal buffer conditions for nucleic acid modification enzymes, and particularly DNA modification enzymes, generally included enough mono- and di-valent salts to allow association of nucleic acid strands by base-pairing. If the method of the present invention is performed using an enzymatic cleavage agent other than those specifically described here, the reactions may generally be performed in any such buffer reported to be optimal for the nuclease function of the cleavage agent. In general, to test the utility of any cleavage agent in this method, test reactions are performed wherein the cleavage agent of interest is tested in the MOPS/MnCl₂/KCl buffer or Mg-containing buffers described herein and in whatever buffer has been reported to be suitable for use with that agent, in a manufacturer's data sheet, a journal article, or in personal communication.

The products of the invader-directed cleavage reaction are fragments generated by structure-specific cleavage of the input oligonucleotides. The resulting cleaved and/or uncleaved oligonucleotides may be analyzed and resolved by a number of methods including electrophoresis (on a variety of supports including acrylamide or agarose gels, paper, etc.), chromatography, fluorescence polarization, mass spectrometry and chip hybridization. The invention is illustrated using electrophoretic separation for the analysis of the products of the cleavage reactions. However, it is noted that the resolution of the cleavage products is not limited to electrophoresis. Electrophoresis is chosen to illustrate the method of the invention because electrophoresis is widely practiced in the art and is easily accessible to the average practitioner.

The probe and invader oligonucleotides may contain a label to aid in their detection following the cleavage reaction. The label may be a radioisotope (e.g., a ³²P or ³⁵S-labelled nucleotide) placed at either the 5' or 3' end of the oligonucleotide or alternatively, the label may be distributed throughout the oligonucleotide (i.e., a uniformly labelled oligonucleotide). The label may be a nonisotopic detectable moiety, such as a fluorophore, which can be detected directly, or a reactive group which permits specific recognition by a secondary agent. For example, biotinylated oligonucleotides may be detected by probing with a streptavidin molecule which is coupled to an indicator (e.g., alkaline phosphatase or a fluorophore) or a hapten such as digoxigenin may be detected using a specific antibody coupled to a similar indicator.

Optimization Of Reaction Conditions

The invader-directed cleavage reaction is useful to detect the presence of specific nucleic acids. In addition to the considerations listed above for the selection and design of the invader and probe oligonucleotides, the conditions under which the reaction is to be performed may be optimized for detection of a specific target sequence.

One objective in optimizing the invader-directed cleavage assay is to allow specific detection of the fewest copies of a target nucleic acid. To achieve this end, it is desirable that the combined elements of the reaction interact with the maximum efficiency, so that the rate of the reaction (*e.g.*, the number of cleavage events per minute) is maximized. Elements contributing to the overall efficiency of the reaction include the rate of hybridization, the rate of cleavage, and the efficiency of the release of the cleaved probe.

The rate of cleavage will be a function of the cleavage means chosen, and may be made optimal according to the manufacturer's instructions when using commercial preparations of enzymes or as described in the examples herein. The other elements (rate of hybridization, efficiency of release) depend upon the execution of the reaction, and optimization of these elements is discussed below.

Three elements of the cleavage reaction that significantly affect the rate of nucleic acid hybridization are the concentration of the nucleic acids, the temperature at which the cleavage reaction is performed and the concentration of salts and/or other charge-shielding ions in the reaction solution.

The concentrations at which oligonucleotide probes are used in assays of this type are well known in the art, and are discussed above. One example of a common approach to optimizing an oligonucleotide concentration is to choose a starting amount of oligonucleotide for pilot tests: 0.01 to 2 μ M is a concentration range used in many oligonucleotide-based assays. When initial cleavage reactions are performed, the following questions may be asked of the data: Is the reaction performed in the absence of the target nucleic acid substantially free of the cleavage product?; Is the site of cleavage specifically shifted in accordance with the design of the invader oligonucleotide?; Is the specific cleavage product easily detected in the presence of the uncleaved probe (or is the amount of uncut material overwhelming the chosen visualization method)?

A negative answer to any of these questions would suggest that the probe concentration is too high, and that a set of reactions using serial dilutions of the probe should be performed until the appropriate amount is identified. Once identified for a given target

nucleic acid in a give sample type (*e.g.*, purified genomic DNA, body fluid extract, lysed bacterial extract), it should not need to be re-optimized. The sample type is important because the complexity of the material present may influence the probe optimum.

Conversely, if the chosen initial probe concentration is too low, the reaction may be slow, due to inefficient hybridization. Tests with increasing quantities of the probe will identify the point at which the concentration exceeds the optimum. Since the hybridization will be facilitated by excess of probe, it is desirable, but not required, that the reaction be performed using probe concentrations just below this point.

The concentration of invader oligonucleotide can be chosen based on the design considerations discussed above. In a preferred embodiment, the invader oligonucleotide is in excess of the probe oligonucleotide. In a particularly preferred embodiment, the invader is approximately 10-fold more abundant than the probe.

Temperature is also an important factor in the hybridization of oligonucleotides. The range of temperature tested will depend in large part, on the design of the oligonucleotides, as discussed above. In a preferred embodiment, the reactions are performed at temperatures slightly below the T_m of the least stable oligonucleotide in the reaction. Melting temperatures for the oligonucleotides and for their component regions (X, Y and Z, Fig. 25), can be estimated through the use of computer software or, for a more rough approximation, by assigning the value of 2°C per A-T basepair, and 4°C per G-C basepair, and taking the sum across an expanse of nucleic acid. The latter method may be used for oligonucleotides of approximately 10-30 nucleotides in length. Because even computer prediction of the T_m of a nucleic acid is only an approximation, the reaction temperatures chosen for initial tests should bracket the calculated T_m . While optimizations are not limited to this, 5°C increments are convenient test intervals in these optimization assays.

When temperatures are tested, the results can be analyzed for specificity (the first two of the questions listed above) in the same way as for the oligonucleotide concentration determinations. Non-specific cleavage (*i.e.*, cleavage of the probe at many or all positions along its length) would indicate non-specific interactions between the probe and the sample material, and would suggest that a higher temperature should be employed. Conversely, little or no cleavage would suggest that even the intended hybridization is being prevented, and would suggest the use of lower temperatures. By testing several temperatures, it is possible to identify an approximate temperature optimum, at which the rate of specific cleavage of the probe is highest. If the oligonucleotides have been designed as described above, the T_m of the

Z-region of the probe oligonucleotide should be below this temperature, so that turnover is assured.

A third determinant of hybridization efficiency is the salt concentration of the reaction. In large part, the choice of solution conditions will depend on the requirements of the cleavage agent, and for reagents obtained commercially, the manufacturer's instructions are a resource for this information. When developing an assay utilizing any particular cleavage agent, the oligonucleotide and temperature optimizations described above should be performed in the buffer conditions best suited to that cleavage agent.

A "no enzyme" control allows the assessment of the stability of the labeled oligonucleotides under particular reaction conditions, or in the presence of the sample to be tested (*i.e.*, in assessing the sample for contaminating nucleases). In this manner, the substrate and oligonucleotides are placed in a tube containing all reaction components, except the enzyme and treated the same as the enzyme-containing reactions. Other controls may also be included. For example, a reaction with all of the components except the target nucleic acid will serve to confirm the dependence of the cleavage on the presence of the target sequence.

Probing For Multiple Alleles

The invader-directed cleavage reaction is also useful in the detection and quantification of individual variants or alleles in a mixed sample population. By way of example, such a need exists in the analysis of tumor material for mutations in genes associated with cancers. Biopsy material from a tumor can have a significant complement of normal cells, so it is desirable to detect mutations even when present in fewer than 5% of the copies of the target nucleic acid in a sample. In this case, it is also desirable to measure what fraction of the population carries the mutation. Similar analyses may also be done to examine allelic variation in other gene systems, and it is not intended that the method of the present invention be limited to the analysis of tumors.

As demonstrated below, reactions can be performed under conditions that prevent the cleavage of probes bearing even a single-nucleotide difference mismatch within the region of the target nucleic acid termed "Z" in Fig. 25, but that permit cleavage of a similar probe that is completely complementary to the target in this region. Thus, the assay may be used to quantitate individual variants or alleles within a mixed sample.

The use of multiple, differently labelled probes in such an assay is also contemplated. To assess the representation of different variants or alleles in a sample, one would provide a

mixture of probes such that each allele or variant to be detected would have a specific probe (*i.e.*, perfectly matched to the Z region of the target sequence) with a unique label (*e.g.*, no two variant probes with the same label would be used in a single reaction). These probes would be characterized in advance to ensure that under a single set of reaction conditions, they could be made to give the same rate of signal accumulation when mixed with their respective target nucleic acids. Assembly of a cleavage reaction comprising the mixed probe set, a corresponding invader oligonucleotide, the target nucleic acid sample, and the appropriate cleavage agent, along with performance of the cleavage reaction under conditions such that only the matched probes would cleave, would allow independent quantification of each of the species present, and would therefore indicate their relative representation in the target sample.

III. A Comparison Of Invasive Cleavage And Primer-Directed Cleavage

As discussed herein, the terms "invasive" or "invader-directed" cleavage specifically denote the use of a first, upstream oligonucleotide, as defined below, to cause specific cleavage at a site within a second, downstream sequence. To effect such a direction of cleavage to a region within a duplex, it is required that the first and second oligonucleotides overlap in sequence. That is to say, a portion of the upstream oligonucleotide, termed the "invader", has significant homology to a portion of the downstream "probe" oligonucleotide, so that these regions would tend to basepair with the same complementary region of the target nucleic acid to be detected. While not limiting the present invention to any particular mechanism, the overlapping regions would be expected to alternate in their occupation of the shared hybridization site. When the probe oligonucleotide fully anneals to the target nucleic acid, and thus forces the 3' region of the invader to remain unpaired, the structure so formed is not a substrate for the 5' nucleases of the present invention. By contrast, when the inverse is true, the structure so formed is substrate for these enzymes, allowing cleavage and release of the portion of the probe oligonucleotide that is displaced by the invader oligonucleotide. The shifting of the cleavage site to a region the probe oligonucleotide that would otherwise be basepaired to the target sequence is one hallmark of the invasive cleavage assay (*i.e.*, the invader-directed cleavage assay) of the present invention.

It is beneficial at this point to contrast the invasive cleavage as described above with two other forms of probe cleavage that may lead to internal cleavage of a probe oligonucleotide, but which do not comprise invasive cleavage. In the first case, a hybridized

probe may be subject to duplex-dependent 5' to 3' exonuclease "nibbling," such that the oligonucleotide is shortened from the 5' end until it cannot remain bound to the target (*see, e.g., Examples 5-7 and Figs. 26-28*). The site at which such nibbling stops can appear to be discrete, and, depending on the difference between the melting temperature of the full-length probe and the temperature of the reaction, this stopping point may be 1 or several nucleotides into the probe oligonucleotide sequence. Such "nibbling" is often indicated by the presence of a "ladder" of longer products ascending size up to that of the full length of the probe, but this is not always the case. While any one of the products of such a nibbling reaction may be made to match in size and cleavage site the products of an invasive cleavage reaction, the creation of these nibbling products would be highly dependent on the temperature of the reaction and the nature of the cleavage agent, but would be independent of the action of an upstream oligonucleotide, and thus could not be construed to involve invasive cleavage.

A second cleavage structure that may be considered is one in which a probe oligonucleotide has several regions of complementarity with the target nucleic acid, interspersed with one or more regions or nucleotides of noncomplementarity. These noncomplementary regions may be thought of as "bubbles" within the nucleic acid duplex. As temperature is elevated, the regions of complementarity can be expected to "melt" in the order of their stability, lowest to highest. When a region of lower stability is near the end of a segment of duplex, and the next region of complementarity along the strand has a higher melting temperature, a temperature can be found that will cause the terminal region of duplex to melt first, opening the first bubble, and thereby creating a preferred substrate structure of the cleavage by the 5' nucleases of the present invention (Fig. 36A). The site of such cleavage would be expected to be on the 5' arm, within 2 nucleotides of the junction between the single and double-stranded regions (Lyamichev *et al., supra.* and U.S. Patent No. 5,422,253)

An additional oligonucleotide could be introduced to basepair along the target nucleic acid would have a similar effect of opening this bubble for subsequent cleavage of the unpaired 5' arm (Fig. 36B and Fig. 6). Note in this case, the 3' terminal nucleotides of the upstream oligonucleotide anneals along the target nucleic acid sequence in such a manner that the 3' end is located within the "bubble" region. Depending on the precise location of the 3' end of this oligonucleotide, the cleavage site may be along the newly unpaired 5' arm, or at the site expected for the thermally opened bubble structure as described above. In the former case the cleavage is not within a duplexed region, and is thus not invasive cleavage, while in

the latter the oligonucleotide is merely an aide in inducing cleavage at a site that might otherwise be exposed through the use of temperature alone (*i.e.* in the absence of the additional oligonucleotide), and is thus not considered to be invasive cleavage.

In summary, any arrangement of oligonucleotides used for the cleavage-based
5 detection of a target sequence can be analyzed to determine if the arrangement is an invasive cleavage structure as contemplated herein. An invasive cleavage structure supports cleavage of the probe in a region that, in the absence of an upstream oligonucleotide, would be expected to be basepaired to the target nucleic acid.

Example 26 below provides further guidance for the design and execution of a
10 experiments which allow the determination of whether a given arrangement of a pair of upstream and downstream (*i.e.* the probe) oligonucleotides when annealed along a target nucleic acid would form an invasive cleavage structure.

IV. Fractionation Of Specific Nucleic Acids By Selective Charge Reversal

15 Some nucleic acid-based detection assays involve the elongation and/or shortening of oligonucleotide probes. For example, as described herein, the primer-directed, primer-independent, and invader-directed cleavage assays, as well as the "nibbling" assay all involve the cleavage (*i.e.* shortening) of oligonucleotides as a means for detecting the presence of a target nucleic sequence. Examples of other detection assays which involve the shortening of
20 an oligonucleotide probe include the "TaqMan" or nick-translation PCR assay described in U.S. Patent No. 5,210,015 to Gelfand *et al.* (the disclosure of which is herein incorporated by reference), the assays described in U.S. Patent Nos. 4,775,619 and 5,118,605 to Urdea (the disclosures of which are herein incorporated by reference), the catalytic hybridization amplification assay described in U.S. Patent No. 5,403,711 to Walder and Walder (the
25 disclosure of which is herein incorporated by reference), and the cycling probe assay described in U.S. Patents Nos. 4,876,187 and 5,011,769 to Duck *et al.* (the disclosures of which are herein incorporated by reference). Examples of detection assays which involve the elongation of an oligonucleotide probe (or primer) include the polymerase chain reaction (PCR) described in U.S. Patent Nos. 4,683,195 and 4,683,202 to Mullis and Mullis *et al.* (the
30 disclosures of which are herein incorporated by reference) and the ligase chain reaction (LCR) described in U.S. Patent Nos. 5,427,930 and 5,494,810 to Birkenmeyer *et al.* and Barany *et al.* (the disclosures of which are herein incorporated by reference). The above examples are

intended to be illustrative of nucleic acid-based detection assays that involve the elongation and/or shortening of oligonucleotide probes and do not provide an exhaustive list.

Typically, nucleic acid-based detection assays that involve the elongation and/or shortening of oligonucleotide probes require post-reaction analysis to detect the products of the reaction. It is common that, the specific reaction product(s) must be separated from the other reaction components, including the input or unreacted oligonucleotide probe. One detection technique involves the electrophoretic separation of the reacted and unreacted oligonucleotide probe. When the assay involves the cleavage or shortening of the probe, the unreacted product will be longer than the reacted or cleaved product. When the assay involves the elongation of the probe (or primer), the reaction products will be greater in length than the input. Gel-based electrophoresis of a sample containing nucleic acid molecules of different lengths separates these fragments primarily on the basis of size. This is due to the fact that in solutions having a neutral or alkaline pH, nucleic acids having widely different sizes (*i.e.*, molecular weights) possess very similar charge-to-mass ratios and do not separate [Andrews, Electrophoresis, 2nd Edition, Oxford University Press (1986), pp. 153-154]. The gel matrix acts as a molecular sieve and allows nucleic acids to be separated on the basis of size and shape (*e.g.*, linear, relaxed circular or covalently closed supercoiled circles).

Unmodified nucleic acids have a net negative charge due to the presence of negatively charged phosphate groups contained within the sugar-phosphate backbone of the nucleic acid. Typically, the sample is applied to gel near the negative pole and the nucleic acid fragments migrate into the gel toward the positive pole with the smallest fragments moving fastest through the gel.

The present invention provides a novel means for fractionating nucleic acid fragments on the basis of charge. This novel separation technique is related to the observation that positively charged adducts can affect the electrophoretic behavior of small oligonucleotides because the charge of the adduct is significant relative to charge of the whole complex. In addition, to the use of positively charged adducts (*e.g.*, Cy3 and Cy5 fluorescent dyes, the positively charged heterodimeric DNA-binding dyes shown in Fig. 66. etc.), the oligonucleotide may contain amino acids (particularly useful amino acids are the charged amino acids: lysine, arginine, aspartate, glutamate), modified bases, such as amino-modified bases, and/or a phosphonate backbone (at all or a subset of the positions). In addition as discussed further below, a neutral dye or detection moiety (*e.g.*, biotin, streptavidin, etc.)

may be employed in place of a positively charged adduct in conjunction with the use of amino-modified bases and/or a complete or partial phosphonate backbone.

This observed effect is of particular utility in assays based on the cleavage of DNA molecules. Using the assays described herein as an example, when an oligonucleotide is shortened through the action of a Cleavase® enzyme or other cleavage agent, the positive charge can be made to not only significantly reduce the net negative charge, but to actually override it, effectively "flipping" the net charge of the labeled entity. This reversal of charge allows the products of target-specific cleavage to be partitioned from uncleaved probe by extremely simple means. For example, the products of cleavage can be made to migrate towards a negative electrode placed at any point in a reaction vessel, for focused detection without gel-based electrophoresis; Example 24 provides examples of devices suitable for focused detection without gel-based electrophoresis. When a slab gel is used, sample wells can be positioned in the center of the gel, so that the cleaved and uncleaved probes can be observed to migrate in opposite directions. Alternatively, a traditional vertical gel can be used, but with the electrodes reversed relative to usual DNA gels (*i.e.*, the positive electrode at the top and the negative electrode at the bottom) so that the cleaved molecules enter the gel, while the uncleaved disperse into the upper reservoir of electrophoresis buffer.

An important benefit of this type of readout is the absolute nature of the partition of products from substrates, *i.e.*, the separation is virtually 100%. This means that an abundance of uncleaved probe can be supplied to drive the hybridization step of the probe-based assay, yet the unconsumed (*i.e.*, unreacted) probe can, in essence, be subtracted from the result to reduce background by virtue of the fact that the unreacted probe will not migrate to the same pole as the specific reaction product.

Through the use of multiple positively charged adducts, synthetic molecules can be constructed with sufficient modification that the normally negatively charged strand is made nearly neutral. When so constructed, the presence or absence of a single phosphate group can mean the difference between a net negative or a net positive charge. This observation has particular utility when one objective is to discriminate between enzymatically generated fragments of DNA, which lack a 3' phosphate, and the products of thermal degradation, which retain a 3' phosphate (and thus two additional negative charges). Examples 22 and 23 demonstrate the ability to separate positively charged reaction products from a net negatively charged substrate oligonucleotide. As discussed in these examples, oligonucleotides may be transformed from net negative to net positively charged compounds. In Example 23, the

positively charged dye, Cy3 was incorporated at the 5' end of a 22-mer (SEQ ID NO:50) which also contained two amino-substituted residues at the 5' end of the oligonucleotide: this oligonucleotide probe carries a net negative charge. After cleavage, which occurred 2 nucleotides into the probe, the following labelled oligonucleotide was released: 5'-Cy3-
5 AminoT-AminoT-3' (as well as the remaining 20 nucleotides of SEQ ID NO:50). This short fragment bears a net positive charge while the remainder of the cleaved oligonucleotide and the unreacted or input oligonucleotide bear net negative charges.

The present invention contemplates embodiments wherein the specific reaction product produced by any cleavage of any oligonucleotide can be designed to carry a net positive
10 charge while the unreacted probe is charge neutral or carries a net negative charge. The present invention also contemplates embodiments where the released product may be designed to carry a net negative charge while the input nucleic acid carries a net positive charge. Depending on the length of the released product to be detected, positively charged dyes may be incorporated at the one end of the probe and modified bases may be placed along the
15 oligonucleotide such that upon cleavage, the released fragment containing the positively charged dye carries a net positive charge. Amino-modified bases may be used to balance the charge of the released fragment in cases where the presence of the positively charged adduct (e.g., dye) alone is not sufficient to impart a net positive charge on the released fragment. In addition, the phosphate backbone may be replaced with a phosphonate backbone at a level
20 sufficient to impart a net positive charge (this is particularly useful when the sequence of the oligonucleotide is not amenable to the use of amino-substituted bases): Figs. 45 and 46 show the structure of short oligonucleotides containing a phosphonate group on the second T residue). An oligonucleotide containing a fully phosphonate-substituted backbone would be charge neutral (absent the presence of modified charged residues bearing a charge or the
25 presence of a charged adduct) due to the absence of the negatively charged phosphate groups. Phosphonate-containing nucleotides (e.g., methylphosphonate-containing nucleotides are readily available and can be incorporated at any position of an oligonucleotide during synthesis using techniques which are well known in the art.

In essence, the invention contemplates the use of charge-based separation to permit the
30 separation of specific reaction products from the input oligonucleotides in nucleic acid-based detection assays. The foundation of this novel separation technique is the design and use of oligonucleotide probes (typically termed "primers" in the case of PCR) which are "charge balanced" so that upon either cleavage or elongation of the probe it becomes "charge

unbalanced." and the specific reaction products may be separated from the input reactants on the basis of the net charge.

In the context of assays which involve the elongation of an oligonucleotide probe (*i.e.*, a primer), such as is the case in PCR, the input primers are designed to carry a net positive charge. Elongation of the short oligonucleotide primer during polymerization will generate PCR products which now carry a net negative charge. The specific reaction products may then easily be separated and concentrated away from the input primers using the charge-based separation technique described herein (the electrodes will be reversed relative to the description in Example 23 as the product to be separated and concentrated after a PCR will carry a negative charge).

V. Invader™-Directed Cleavage Using Miniprobcs And Mid-Range Probes

As discussed in section III above, the Invader™-directed cleavage assay may be performed using invader and probe oligonucleotides which have a length of about 13-25 nucleotides (typically 20-25 nucleotides). It is also contemplated that the oligonucleotides that span the X, Y and Z regions (see Fig. 25), the invader and probe oligonucleotides, may themselves be composed of shorter oligonucleotide sequences that align along a target strand but that are not covalently linked. This is to say that there is a nick in the sugar-phosphate backbone of the composite oligonucleotide, but that there is no disruption in the progression of base-paired nucleotides in the resulting duplex. When short strands of nucleic acid align contiguously along a longer strand the hybridization of each is stabilized by the hybridization of the neighboring fragments because the basepairs can stack along the helix as though the backbone was in fact uninterrupted. This cooperativity of binding can give each segment a stability of interaction in excess of what would be expected for the segment hybridizing to the longer nucleic acid alone. One application of this observation has been to assemble primers for DNA sequencing, typically about 18 nucleotides long, from sets of three hexamer oligonucleotides that are designed to hybridize in this way [Kotler, L.E., *et al.* (1993) Proc. Natl. Acad. Sci. USA 90:4241]. The resulting doubly-nicked primer can be extended enzymatically in reactions performed at temperatures that might be expected to disrupt the hybridization of hexamers, but not of 18-mers.

The use of composite or split oligonucleotides is applied with success in the Invader™-directed cleavage assay. The probe oligonucleotide may be split into two oligonucleotides which anneal in a contiguous and adjacent manner along a target

oligonucleotide as diagrammed in Fig. 57. In this figure, the downstream oligonucleotide (analogous to the probe of Fig. 25) is assembled from two smaller pieces: a short segment of 6-10 nts (termed the "miniprobe"), that is to be cleaved in the course of the detection reaction, and an oligonucleotide that hybridizes immediately downstream of the miniprobe (termed the "stacker"), which serves to stabilize the hybridization of the probe. To form the cleavage structure, an upstream oligonucleotide (the "Invader™" oligo) is provided to direct the cleavage activity to the desired region of the miniprobe. Assembly of the probe from non-linked pieces of nucleic acid (*i.e.*, the miniprobe and the stacker) allows regions of sequences to be changed without requiring the re-synthesis of the entire proven sequence, thus improving the cost and flexibility of the detection system. In addition, the use of unlinked composite oligonucleotides makes the system more stringent in its requirement of perfectly matched hybridization to achieve signal generation, allowing this to be used as a sensitive means of detecting mutations or changes in the target nucleic acid sequences.

As illustrated in Fig. 57, in one embodiment, the methods of the present invention employ at least three oligonucleotides that interact with a target nucleic acid to form a cleavage structure for a structure-specific nuclease. More specifically, the cleavage structure comprises i) a target nucleic acid that may be either single-stranded or double-stranded (when a double-stranded target nucleic acid is employed, it may be rendered single-stranded, *e.g.*, by heating); ii) a first oligonucleotide, termed the "stacker," which defines a first region of the target nucleic acid sequence by being the complement of that region (region W of the target as shown in Fig. 57); iii) a second oligonucleotide, termed the "miniprobe," which defines a second region of the target nucleic acid sequence by being the complement of that region (regions X and Z of the target as shown in Fig. 57); iv) a third oligonucleotide, termed the "invader," the 5' part of which defines a third region of the same target nucleic acid sequence (regions Y and X in Fig. 57), adjacent to and downstream of the second target region (regions X and Z), and the second or 3' part of which overlaps into the region defined by the second oligonucleotide (region X depicts the region of overlap). The resulting structure is diagrammed in Fig. 57.

While not limiting the invention or the instant discussion to any particular mechanism of action, the diagram in Fig. 57 represents the effect on the site of cleavage caused by this type of arrangement of three oligonucleotides. The design of these three oligonucleotides is described below in detail. In Fig. 57, the 3' ends of the nucleic acids (*i.e.*, the target and the oligonucleotides) are indicated by the use of the arrowheads on the ends of the lines depicting

the strands of the nucleic acids (and where space permits, these ends are also labelled "3'").

It is readily appreciated that the three oligonucleotides (the invader, the miniprobe and the stacker) are arranged in a parallel orientation relative to one another, while the target nucleic acid strand is arranged in an anti-parallel orientation relative to the three oligonucleotides.

5 Further it is clear that the invader oligonucleotide is located upstream of the miniprobe oligonucleotide and that the miniprobe oligonucleotide is located upstream of the stacker oligonucleotide and that with respect to the target nucleic acid strand, region W is upstream of region Z, region Z is upstream of region X and region X is upstream of region Y (that is region Y is downstream of region X, region X is downstream of region Z and region
10 Z is downstream of region W). Regions of complementarity between the opposing strands are indicated by the short vertical lines. While not intended to indicate the precise location of the site(s) of cleavage, the area to which the site of cleavage within the miniprobe oligonucleotide is shifted by the presence of the invader oligonucleotide is indicated by the solid vertical arrowhead. Fig. 57 is not intended to represent the actual mechanism of action or physical
15 arrangement of the cleavage structure and further it is not intended that the method of the present invention be limited to any particular mechanism of action.

It can be considered that the binding of these oligonucleotides divides the target nucleic acid into four distinct regions: one region that has complementarity to only the stacker (shown as "W"); one region that has complementarity to only the miniprobe (shown as
20 "Z"); one region that has complementarity only to the Invader™ oligo (shown as "Y"); and one region that has complementarity to both the Invader™ and miniprobe oligonucleotides (shown as "X").

In addition to the benefits cited above, the use of a composite design for the oligonucleotides which form the cleavage structure allows more latitude in the design of the
25 reaction conditions for performing the Invader™-directed cleavage assay. When a longer probe (e.g., 16-25 nt), as described in section III above, is used for detection in reactions that are performed at temperatures below the T_m of that probe, the cleavage of the probe may play a significant role in destabilizing the duplex of which it is a part, thus allowing turnover and reuse of the recognition site on the target nucleic acid. In contrast, with miniprobos, reaction
30 temperatures that are at or above the T_m of the probe mean that the probe molecules are hybridizing and releasing from the target quite rapidly even without cleavage of the probe. When an upstream Invader™ oligonucleotide and a cleavage means are provided the miniprobe will be specifically cleaved, but the cleavage will not be necessary to the turnover

of the miniprobe. If a long probe (e.g., 16-25 nt) were to be used in this way the temperatures required to achieve this state would be quite high, around 65 to 70°C for a 25-mer of average base composition. Requiring the use of such elevated temperatures limits the choice of cleavage agents to those that are very thermostable, and may contribute to background in the reactions, depending of the means of detection. through thermal degradation of the probe oligonucleotides. Thus, the shorter probes are preferable for use in this way.

The miniprobe of the present invention may vary in size depending on the desired application. In one embodiment, the probe may be relatively short compared to a standard probe (e.g., 16-25 nt), in the range of 6 to 10 nucleotides. When such a short probe is used reaction conditions can be chosen that prevent hybridization of the miniprobe in the absence of the stacker oligonucleotide. In this way a short probe can be made to assume the statistical specificity and selectivity of a longer sequence. In the event of a perturbation in the cooperative binding of the miniprobe and stacker nucleic acids, as might be caused by a mismatch within the short sequence (*i.e.*, region "Z" which is the region of the miniprobe which does not overlap with the invader) or at the junction between the contiguous duplexes, this cooperativity can be lost, dramatically reducing the stability of the shorter oligonucleotide (*i.e.*, the miniprobe), and thus reducing the level of cleaved product in the assay of the present invention.

It is also contemplated that probes of intermediate size may be used. Such probes, in the 11 to 15 nucleotide range, may blend some of the features associated with the longer probes as originally described, these features including the ability to hybridize and be cleaved absent the help of a stacker oligonucleotide. At temperatures below the expected T_m of such probes, the mechanisms of turnover may be as discussed above for probes in the 20 nt range, and be dependent on the removal of the sequence in the 'X' region for destabilization and cycling.

The mid-range probes may also be used at elevated temperatures, at or above their expected T_m , to allow melting rather than cleavage to promote probe turnover. In contrast to the longer probes described above, however, the temperatures required to allow the use of such a thermally driven turnover are much lower (about 40 to 60°C), thus preserving both the cleavage means and the nucleic acids in the reaction from thermal degradation. In this way, the mid-range probes may perform in some instances like the miniprobos described above. In

a further similarity to the miniprobcs, the accumulation of cleavage signal from a mid-range probe may be helped under some reaction conditions by the presence of a stacker.

To summarize, a standard long probe usually does not benefit from the presence of a stacker oligonucleotide downstream (the exception being cases where such an oligonucleotide may also disrupt structures in the target nucleic acid that interfere with the probe binding), and it is usually used in conditions requiring several nucleotides to be removed to allow the oligonucleotide to release from the target efficiently.

The miniprobe is very short and performs optimally in the presence of a downstream stacker oligonucleotide. The miniprobcs are well suited to reactions conditions that use the temperature of the reaction to drive rapid exchange of the probes on the target regardless of whether any bases have been cleaved. In reactions with sufficient amount of the cleavage means, the probes that do bind will be rapidly cleaved before they melt off.

The mid-range or midiprobe combines features of these probes and can be used in reactions like those designed long probes, with longer regions of overlap ("X" regions) to drive probe turnover at lower temperature. In a preferred embodiment, the midrange probes are used at temperatures sufficiently high that the probes are hybridizing to the target and releasing rapidly regardless of cleavage. This is known to be the behavior of oligonucleotides at or near their melting temperature. This mode of turnover is more similar to that used with miniprobe/stacker combinations than with long probes. The mid-range probe may have enhanced performance in the presence of a stacker under some circumstances. For example, with a probe in the lower end of the mid-range, e.g., 11 nt, or one with exceptional A/T content, in a reaction performed well in excess of the T_m of the probe (e.g., $>10^\circ\text{C}$ above) the presence of a stacker would be likely to enhance the performance of the probe, while at a more moderate temperature the probe may be indifferent to a stacker.

The distinctions between the mini-, midi- (i.e., mid-range) and long probes are not contemplated to be inflexible and based only on length. The performance of any given probe may vary with its specific sequence, the choice of solution conditions, the choice of temperature and the selected cleavage means.

It is shown in Example 18 that the assemblage of oligonucleotides that comprises the cleavage structure of the present invention is sensitive to mismatches between the probe and the target. The site of the mismatch used in Ex. 18 provides one example and is not intended to be a limitation in location of a mismatch affecting cleavage. It is also contemplated that a mismatch between the InvaderTM oligonucleotide and the target may be used to distinguish

related target sequences. In the 3-oligonucleotide system, comprising an Invader™, a probe and a stacker oligonucleotide, it is contemplated that mismatches may be located within any of the regions of duplex formed between these oligonucleotides and the target sequence. In a preferred embodiment, a mismatch to be detected is located in the probe. In a particularly preferred embodiment, the mismatch is in the probe, at the basepair immediately upstream (i.e., 5') of the site that is cleaved when the probe is not mismatched to the target.

In another preferred embodiment, a mismatch to be detected is located within the region 'Z' defined by the hybridization of a miniprobe. In a particularly preferred embodiment, the mismatch is in the miniprobe, at the basepair immediately upstream (i.e., 5') of the site that is cleaved when the miniprobe is not mismatched to the target.

It is also contemplated that different sequences may be detected in a single reaction. Probes specific for the different sequences may be differently labeled. For example, the probes may have different dyes or other detectable moieties, different lengths, or they may have differences in net charges of the products after cleavage. When differently labeled in one of these ways, the contribution of each specific target sequence to final product can be tallied. This has application in detecting the quantities of different versions of a gene within a mixture. Different genes in a mixture to be detected and quantified may be wild type and mutant genes, e.g., as may be found in a tumor sample (e.g., a biopsy). In this embodiment, one might design the probes to precisely the same site, but one to match the wild-type sequence and one to match the mutant. Quantitative detection of the products of cleavage from a reaction performed for a set amount of time will reveal the ratio of the two genes in the mixture. Such analysis may also be performed on unrelated genes in a mixture. This type of analysis is not intended to be limited to two genes. Many variants within a mixture may be similarly measured.

Alternatively, different sites on a single gene may be monitored and quantified to verify the measurement of that gene. In this embodiment, the signal from each probe would be expected to be the same.

It is also contemplated that multiple probes may be used that are not differently labeled, such that the aggregate signal is measured. This may be desirable when using many probes designed to detect a single gene to boost the signal from that gene. This configuration may also be used for detecting unrelated sequences within a mix. For example, in blood banking it is desirable to know if any one of a host of infectious agents is present in a sample of blood. Because the blood is discarded regardless of which agent is present, different

signals on the probes would not be required in such an application of the present invention. and may actually be undesirable for reasons of confidentiality.

Just as described for the two-oligonucleotide system, above, the specificity of the detection reaction will be influenced by the aggregate length of the target nucleic acid sequences involved in the hybridization of the complete set of the detection oligonucleotides. For example, there may be applications in which it is desirable to detect a single region within a complex genome. In such a case the set of oligonucleotides may be chosen to require accurate recognition by hybridization of a longer segment of a target nucleic acid, often in the range of 20 to 40 nucleotides. In other instances it may be desirable to have the set of oligonucleotides interact with multiple sites within a target sample. In these cases one approach would be to use a set of oligonucleotides that recognize a smaller, and thus statistically more common, segment of target nucleic acid sequence.

In one preferred embodiment, the invader and stacker oligonucleotides may be designed to be maximally stable, so that they will remain bound to the target sequence for extended periods during the reaction. This may be accomplished through any one of a number of measures well known to those skilled in the art, such as adding extra hybridizing sequences to the length of the oligonucleotide (up to about 50 nts in total length), or by using residues with reduced negative charge, such as phosphorothioates or peptide-nucleic acid residues, so that the complementary strands do not repel each other to degree that natural strands do. Such modifications may also serve to make these flanking oligonucleotides resistant to contaminating nucleases, thus further ensuring their continued presence on the target strand during the course of the reaction. In addition, the Invader™ and stacker oligonucleotides may be covalently attached to the target (*e.g.*, through the use of psoralen cross-linking).

The use of the reaction temperatures at or near the T_m of the probe oligonucleotide, rather than that used for cleavage, to drive the turnover of the probe oligonucleotide in these detection reactions means that the amount of the probe oligonucleotide cleaved off may be substantially reduced without adversely affecting the turnover rate. It has been determined that the relationship between the 3' end of the upstream oligonucleotide and the desired site of cleavage on the probe must be carefully designed. It is known that the preferred site of cleavage for the types of structure specific endonucleases employed herein is one basepair into a duplex (Lyamichev *et al.*, *supra*). It was previously believed that the presence of an upstream oligonucleotide or primer allowed the cleavage site to be shifted away from this

preferred site, into the single stranded region of the 5' arm (Lyamichev *et al.*, *supra* and U.S. Patent No. 5,422,253). In contrast to this previously proposed mechanism, and while not limiting the present invention to any particular mechanism, it is believed that the nucleotide immediately 5', or upstream of the cleavage site on the probe (including miniprobe and mid-range probes) must be able to basepair with the target for efficient cleavage to occur. In the case of the present invention, this would be the nucleotide in the probe sequence immediately upstream of the intended cleavage site. In addition, as described herein, it has been observed that in order to direct cleavage to that same site in the probe, the upstream oligonucleotide must have its 3' base (*i.e.*, nt) immediately upstream of the intended cleavage site of the probe. This places the 3' terminal nucleotide of the upstream oligonucleotide and the base of the probe oligonucleotide 5' of the cleavage site in competition for pairing with the corresponding nucleotide of the target strand.

To examine the outcome of this competition, *i.e.* which base is paired during a successful cleavage event, substitutions were made in the probe and invader oligonucleotides such that either the probe or the Invader™ oligonucleotide were mismatched with the target sequence at this position. The effects of both arrangements on the rates of cleavage were examined. When the Invader™ oligonucleotide is unpaired at the 3' end, the rate of cleavage was not reduced. If this base was removed, however, the cleavage site was shifted upstream of the intended site. In contrast, if the probe oligonucleotide was not base-paired to the target just upstream of the site to which the Invader™ oligonucleotide was directing cleavage, the rate of cleavage was dramatically reduced, suggesting that when a competition exists, the probe oligonucleotide was the molecule to be base-paired in this position.

It appears that the 3' end of the upstream invader oligonucleotide is unpaired during cleavage, and yet is required for accurate positioning of the cleavage. To examine which part(s) of the 3' terminal nucleotide are required for the positioning of cleavage, Invader™ oligonucleotides were designed that terminated on this end with nucleotides that were altered in a variety of ways. Sugars examined included 2' deoxyribose with a 3' phosphate group, a dideoxyribose, 3' deoxyribose, 2' O-methyl ribose, arabinose and arabinose with a 3' phosphate. Abasic ribose, with and without 3' phosphate were tested. Synthetic "universal" bases such as 3-nitropyrrole and 5-nitroindole on ribose sugars were tested. Finally, a base-like aromatic ring structure, acridine, linked to the 3' end the previous nucleotide without a sugar group was tested. The results obtained support the conclusion that the aromatic ring of

the base (at the 3' end of the invader oligonucleotide) is the required moiety for accomplishing the direction of cleavage to the desired site within the downstream probe.

VI. Signal Enhancement By Tailing Of Reaction Products In The Invader™.

5 Directed Cleavage Assay

It has been determined that when oligonucleotide probes are used in cleavage detection assays at elevated temperature, some fraction of the truncated probes will have been shortened by nonspecific thermal degradation, and that such breakage products can make the analysis of the target-specific cleavage data more difficult. Background cleavage such as this can, when
10 not resolved from specific cleavage products, reduce the accuracy of quantitation of target nucleic acids based on the amount of accumulated product in a set timeframe. One means of distinguishing the specific from the nonspecific products is disclosed above, and is based on partitioning the products of these reactions by differences in the net charges carried by the different molecular species in the reaction. As was noted in that discussion, the thermal
15 breakage products usually retain 3' phosphates after breakage, while the enzyme-cleaved products do not. The two negative charges on the phosphate facilitate charge-based partition of the products.

The absence of a 3' phosphate on the desired subset of the probe fragments may be used to advantage in enzymatic assays as well. Nucleic acid polymerases, both non-templated
20 (e.g., terminal deoxynucleotidyl transferase, polyA polymerase) and template-dependent (e.g., Pol I-type DNA polymerases), require an available 3' hydroxyl by which to attach further nucleotides. This enzymatic selection of 3' end structure may be used as an effective means of partitioning specific from non-specific products.

In addition to the benefits of the partitioning described above, the addition of
25 nucleotides to the end of the specific product of an invader-specific cleavage offers an opportunity to either add label to the products, to add capturable tails to facilitate solid-support based readout systems, or to do both of these things at the same time. Some possible embodiments of this concept are illustrated in Fig. 56.

In Fig. 56, an Invader™ cleavage structure comprising an Invader™ oligonucleotide
30 containing a blocked or non-extendible 3' end (e.g., a 3' dideoxynucleotide) and a probe oligonucleotide containing a blocked or non-extendible 3' end (the open circle at the 3' end of the oligonucleotides represents a non-extendible nucleotide) and a target nucleic acid is shown: the probe oligonucleotide may contain a 5' end label such as a biotin or a fluorescein

(indicated by the stars) label (cleavage structures which employ a 5' biotin-labeled probe or a 5' fluorescein-labeled probe are shown below the large diagram of the cleavage structure to the left and the right, respectively). Following, cleavage of the probe (the site of cleavage is indicated by the large arrowhead), the cleaved biotin-labeled probe is extended using a
5 template-independent polymerase (*e.g.*, TdT) and fluoresceinated nucleotide triphosphates. The fluorescein tailed cleaved probe molecule is then captured by binding via its 5' biotin label to streptavidin and the fluorescence is then measured. Alternatively, following, cleavage of a 5'-fluoresceinated probe, the cleaved probe is extended using a template-independent polymerase (*e.g.*, TdT) and dATP. The polyadenylated (A-tailed) cleaved probe molecule is
10 then captured by binding via the polyA tail to oligo dT attached to a solid support.

The examples described in Fig. 56 are based on the use of TdT to tail the specific products of Invader™-directed cleavage. The description of the use of this particular enzyme is presented by way of example and is not intended as a limitation (indeed, when probe oligos comprising RNA are employed, cleaved RNA probes may be extended using polyA
15 polymerase). It is contemplated that an assay of this type could be configured to use a template-dependent polymerase, as described above. While this would require the presence of a suitable copy template distinct from the target nucleic acid, on which the truncated oligonucleotide could prime synthesis, it can be envisaged that a probe which before cleavage would be unextendible, due to either mismatch or modification of the 3' end, could be
20 activated as a primer when cleaved by an invader directed cleavage. A template directed tailing reaction also has the advantage of allowing greater selection and control of the nucleotides incorporated.

The use of nontemplated tailing does not require the presence of any additional nucleic acids in the detection reaction, avoiding one step of assay development and troubleshooting.
25 In addition, the use of non templated synthesis eliminated the step of hybridization, potentially speeding up the assay. Furthermore, the TdT enzyme is fast, able to add at least >700 nucleotides to substrate oligonucleotides in a 15 minute reaction.

As mentioned above, the tails added can be used in a number of ways. It can be used as a straight-forward way of adding labeled moieties to the cleavage product to increase signal
30 from each cleavage event. Such a reaction is depicted in the left side of Fig. 66. The labeled moieties may be anything that can, when attached to a nucleotide, be added by the tailing enzyme, such as dye molecules, haptens such as digoxigenin, or other binding groups such as biotin.

In a preferred embodiment the assay includes a means of specifically capturing or partitioning the tailed invader-directed cleavage products in the mixture. It can be seen that target nucleic acids in the mixture may be tailed during the reaction. If a label is added, it is desirable to partition the tailed invader-directed cleavage products from these other labeled molecules to avoid background in the results. This is easily done if only the cleavage product is capable of being captured. For example, consider a cleavage assay of the present invention in which the probe used has a biotin on the 5' end and is blocked from extension on the 3' end, and in which a dye is added during tailing. Consider further that the products are to be captured onto a support via the biotin moiety, and the captured dye measured to assess the presence of the target nucleic acid. When the label is added by tailing, only the specifically cleaved probes will be labeled. The residual uncut probes can still bind in the final capture step, but they will not contribute to the signal. In the same reaction, nicks and cuts in the target nucleic acid may be tailed by the enzyme, and thus become dye labeled. In the final capture these labeled targets will not bind to the support and thus, though labeled, they will not contribute to the signal. If the final specific product is considered to consist of two portions, the probe-derived portion and the tail portion, can be seen from this discussion that it is particularly preferred that when the probe-derived portion is used for specific capture, whether by hybridization, biotin/streptavidin, or other method, that the label be associated with the tail portion. Conversely, if a label is attached to the probe-derived portion, then the tail portion may be made suitable for capture, as depicted on the right side of Fig. 66. Tails may be captured in a number of ways, including hybridization, biotin incorporation with streptavidin capture, or by virtue of the fact that the longer molecules bind more predictably and efficiently to a number of nucleic acid binding matrices, such as nitrocellulose, nylon, or glass, in membrane, paper, resin, or other form. While not required for this assay, this separation of functions allows effective exclusion from signal of both unreacted probe and tailed target nucleic acid.

In addition to the supports described above, the tailed products may be captured onto any support that contains a suitable capture moiety. For example, biotinylated products are generally captured with avidin-treated surfaces. These avidin surfaces may be in microtitre plate wells, on beads, on dipsticks, to name just a few of the possibilities. Such surfaces can also be modified to contain specific oligonucleotides, allowing capture of product by hybridization. Capture surfaces as described here are generally known to those skilled in the art and include nitrocellulose dipsticks (e.g., GeneComb™, BioRad, Hercules, CA).

VII. Improved Enzymes For Use In Invader™-Directed Cleavage Reactions

A cleavage structure is defined herein as a structure which is formed by the interaction of a probe oligonucleotide and a target nucleic acid to form a duplex, the resulting structure being cleavable by a cleavage means, including but not limited to an enzyme. The
5 cleavage structure is further defined as a substrate for specific cleavage by the cleavage means in contrast to a nucleic acid molecule which is a substrate for nonspecific cleavage by agents such as phosphodiesterases. Examples of some possible cleavage structures are shown in Fig. 15. In considering improvements to enzymatic cleavage means, one may consider the action of said enzymes on any of these structures, and on any other structures that fall within the
10 definition of a cleavage structure. The cleavage sites indicated on the structures in Fig. 15 are presented by way of example. Specific cleavage at any site within such a structure is contemplated.

Improvements in an enzyme may be an increased or decreased rate of cleavage of one or more types of structures. Improvements may also result in more or fewer sites of cleavage
15 on one or more of said cleavage structures. In developing a library of new structure-specific nucleases for use in nucleic acid cleavage assays, improvements may have many different embodiments, each related to the specific substrate structure used in a particular assay.

As an example, one embodiment of the Invader™-directed cleavage assay of the present invention may be considered. In the Invader™ directed cleavage assay, the
20 accumulation of cleaved material is influenced by several features of the enzyme behavior. Not surprisingly, the turnover rate, or the number of structures that can be cleaved by a single enzyme molecule in a set amount of time, is very important in determining the amount of material processed during the course of an assay reaction. If an enzyme takes a long time to recognize a substrate (*e.g.*, if it is presented with a less-than-optimal structure), or if it takes a
25 long time to execute cleavage, the rate of product accumulation is lower than if these steps proceeded quickly. If these steps are quick, yet the enzyme "holds on" to the cleaved structure, and does not immediately proceed to another uncut structure, the rate will be negatively affected.

Enzyme turnover is not the only way in which enzyme behavior can negatively affect
30 the rate of accumulation of product. When the means used to visualize or measure product is specific for a precisely defined product, products that deviate from that definition may escape detection, and thus the rate of product accumulation may appear to be lower than it is. For example, if one had a sensitive detector for trinucleotides that could not see di- or

tetranucleotides, or any sized oligonucleotide other than 3 residues, in the Invader™-directed cleavage assay of the present invention any errant cleavage would reduce the detectable signal proportionally. It can be seen from the cleavage data presented here that, while there is usually one site within a probe that is favored for cleavage, there are often products that arise from cleavage one or more nucleotides away from the primary cleavage site. These are products that are target dependent, and are thus not non-specific background. Nevertheless, if a subsequent visualization system can detect only the primary product, these represent a loss of signal. One example of such a selective visualization system is the charge reversal readout presented herein, in which the balance of positive and negative charges determines the behavior of the products. In such a system the presence of an extra nucleotide or the absence of an expected nucleotide can exclude a legitimate cleavage product from ultimate detection by leaving that product with the wrong balance of charge. It can be easily seen that any assay that can sensitively distinguish the nucleotide content of an oligonucleotide, such as standard stringent hybridization, suffers in sensitivity when some fraction of the legitimate product is not eligible for successful detection by that assay.

These discussions suggest two highly desirable traits in any enzyme to be used in the method of the present invention. First, the more rapidly the enzyme executes an entire cleavage reaction, including recognition, cleavage and release, the more signal it may potentially create in the invader-directed cleavage assay. Second, the more successful an enzyme is at focusing on a single cleavage site within a structure, the more of the cleavage product can be successfully detected in a selective read-out.

The rationale cited above for making improvements in enzymes to be used in the Invader™-directed cleavage assay are meant to serve as an example of one direction in which improvements might be sought, but not as a limit on either the nature or the applications of improved enzyme activities. As another direction of activity change that would be appropriately considered improvement, the DNAP-associated 5' nucleases may be used as an example. In creating some of the polymerase-deficient 5' nucleases described herein it was found that those that were created by deletion of substantial portions of the polymerase domain, as depicted in Fig. 4, assumed activities that were weak or absent in the parent proteins. These activities included the ability to cleave the non-forked structure shown in Fig. 15D, a greatly enhanced ability to exonucleolytically remove nucleotides from the 5' ends of duplexed strands, and a nascent ability to cleave circular molecules without benefit of a free 5' end.

In addition to the 5' nucleases derived from DNA polymerases, the present invention also contemplates the use of structure-specific nucleases that are not derived from DNA polymerases. For example, a class of eukaryotic and archaebacterial endonucleases have been identified which have a similar substrate specificity to 5' nucleases of Pol I-type DNA
5 polymerases. These are the FEN1 (Flap EndoNuclease), RAD2, and XPG (Xeroderma Pigmentosa-complementation group G) proteins. These proteins are involved in DNA repair, and have been shown to favor the cleavage of structures that resemble a 5' arm that has been displaced by an extending primer during polymerization, similar to the model depicted in Fig. 15B. Similar DNA repair enzymes have been isolated from single cell and higher eukaryotes
10 and from archaea, and there are related DNA repair proteins in eubacteria. Similar 5' nucleases have also be associated with bacteriophage such as T5 and T7.

Recently, the 3-dimensional structures of DNAP_{Taq} and T5 phage 5'-exonuclease (Fig. 58) were determined by X-ray diffraction [Kim *et al.* (1995) Nature 376:612 and Ceska
15 *et al.* (1995) Nature 382:90]. The two enzymes have very similar 3-dimensional structures despite limited amino acid sequence similarity. The most striking feature of the T5 5'-exonuclease structure is the existence of a triangular hole formed by the active site of the protein and two alpha helices (Fig. 58). This same region of DNAP_{Taq} is disordered in the crystal structure, indicating that this region is flexible, and thus is not shown in the published 3-dimensional structure. However, the 5' nuclease domain of DNAP_{Taq} is likely to have the
20 same structure, based its overall 3-dimensional similarity to T5 5'-exonuclease, and that the amino acids in the disordered region of the DNAP_{Taq} protein are those associated with alpha helix formation. The existence of such a hole or groove in the 5' nuclease domain of DNAP_{Taq} was predicted based on its substrate specificity [Lyamichev *et al.*, *supra*].

It has been suggested that the 5' arm of a cleavage structure must thread through the
25 helical arch described above to position said structure correctly for cleavage (Ceska *et al.*, *supra*). One of the modifications of 5' nucleases described herein opened up the helical arch portion of the protein to allow improved cleavage of structures that cut poorly or not at all (*e.g.*, structures on circular DNA targets that would preclude such threading of a 5' arm). The gene construct that was chosen as a model to test this approach was the one called
30 Cleavase® BN, which was derived from DNAP_{Taq} but does not contain the polymerase domainn (Ex. 2). It comprises the entire 5' nuclease domain of DNAP_{Taq}, and thus should be very close in structure to the T5 5' exonuclease. This 5' nuclease was chosen to demonstrate the principle of such a physical modification on proteins of this type. The

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arch-opening modification of the present invention is not intended to be limited to the 5' nuclease domains of DNA polymerases, and is contemplated for use on any structure-specific nuclease which includes such an aperture as a limitation on cleavage activity. The present invention contemplates the insertion of a thrombin cleavage site into the helical arch of
5 DNAPs derived from the genus *Thermus* as well as 5' nucleases derived from DNAPs derived from the genus *Thermus*. The specific example shown herein using the Cleavase® BN/thrombin nuclease merely illustrates the concept of opening the helical arch located within a nuclease domain. As the amino acid sequence of DNAPs derived from the genus *Thermus* are highly conserved, the teachings of the present invention enable the insertion of a thrombin
10 site into the helical arch present in these DNAPs and 5' nucleases derived from these DNAPs.

The opening of the helical arch was accomplished by insertion of a protease site in the arch. This allowed post-translational digestion of the expressed protein with the appropriate protease to open the arch at its apex. Proteases of this type recognize short stretches of specific amino acid sequence. Such proteases include thrombin and factor Xa. Cleavage of a
15 protein with such a protease depends on both the presence of that site in the amino acid sequence of the protein and the accessibility of that site on the folded intact protein. Even with a crystal structure it can be difficult to predict the susceptibility of any particular region of a protein to protease cleavage. Absent a crystal structure it must be determined empirically.

20 In selecting a protease for a site-specific cleavage of a protein that has been modified to contain a protease cleavage site, a first step is to test the unmodified protein for cleavage at alternative sites. For example, DNAPtaq and Cleavase® BN nuclease were both incubated under protease cleavage conditions with factor Xa and thrombin proteases. Both nuclease proteins were cut with factor Xa within the 5' nuclease domain, but neither nuclease was
25 digested with large amounts of thrombin. Thus, thrombin was chosen for initial tests on opening the arch of the Cleavase® BN enzyme.

In the protease/Cleavase® modifications described herein the factor Xa protease cleaved strongly in an unacceptable position in the unmodified nuclease protein, in a region likely to compromise the activity of the end product. Other unmodified nucleases
30 contemplated herein may not be sensitive to the factor Xa, but may be sensitive to thrombin or other such proteases. Alternatively, they may be sensitive to these or other such proteases at sites that are immaterial to the function of the nuclease sought to be modified. In approaching any protein for modification by addition of a protease cleavage site, the

unmodified protein should be tested with the proteases under consideration to determine which proteases give acceptable levels of cleavage in other regions.

Working with the cloned segment of DNAPTaq from which the Cleavase® BN protein is expressed, nucleotides encoding a thrombin cleavage site were introduced in-frame near the sequence encoding amino acid 90 of the nuclease gene. This position was determined to be at or near the apex of the helical arch by reference to both the 3-dimensional structure of DNAPTaq, and the structure of T5 5' exonuclease. The encoded amino acid sequence, LVPRGS, was inserted into the apex of the helical arch by site-directed mutagenesis of the nuclease gene. The proline (P) in the thrombin cleavage site was positioned to replace a proline normally in this position in Cleavase® BN because proline is an alpha helix-breaking amino acid, and may be important for the 3-dimensional structure of this arch. This construct was expressed, purified and then digested with thrombin. The digested enzyme was tested for its ability to cleave a target nucleic acid, bacteriophage M13 genomic DNA, that does not provide free 5' ends to facilitate cleavage by the threading model.

While the helical arch in this nuclease was opened by protease cleavage, it is contemplated that a number of other techniques could be used to achieve the same end. For example, the nucleotide sequence could be rearranged such that, upon expression, the resulting protein would be configured so that the top of the helical arch (amino acid 90) would be at the amino terminus of the protein, the natural carboxyl and amino termini of the protein sequence would be joined, and the new carboxyl terminus would lie at natural amino acid 89. This approach has the benefit that no foreign sequences are introduced and the enzyme is a single amino acid chain, and thus may be more stable than the cleaved 5' nuclease. In the crystal structure of DNAPTaq, the amino and carboxyl termini of the 5'-exonuclease domain lie in close proximity to each other, which suggests that the ends may be directly joined without the use of a flexible linker peptide sequence as is sometimes necessary. Such a rearrangement of the gene, with subsequent cloning and expression could be accomplished by standard PCR recombination and cloning techniques known to those skilled in the art.

The present invention also contemplates the use of nucleases isolated from organisms that grow under a variety of conditions. The genes for the FEN-1/XPG class of enzymes are found in organisms ranging from bacteriophage to humans to the extreme thermophiles of Kingdom Archaea. For assays in which high temperature is to be used, it is contemplated that enzymes isolated from extreme thermophiles may exhibit the thermostability required of such an assay. For assays in which it might be desirable to have peak enzyme activity at moderate

temperature or in which it might be desirable to destroy the enzyme with elevated temperature. those enzymes from organisms that favor moderate temperatures for growth may be of particular value.

An alignment of a collection of FEN-1 proteins sequenced by others is shown in Figs. 59A-E (SEQ ID NOS:135-145). It can be seen from this alignment that there are some regions of conservation in this class of proteins, suggesting that they are related in function, and possibly in structure. Regions of similarity at the amino acid sequence level can be used to design primers for *in vitro* amplification (PCR) by a process of back translating the amino acid sequence to the possible nucleic acid sequences, then choosing primers with the fewest possible variations within the sequences. These can be used in low stringency PCR to search for related DNA sequences. This approach permits the amplification of DNA encoding a FEN-1 nuclease without advance knowledge of the actual DNA sequence.

It can also be seen from this alignment that there are regions in the sequences that are not completely conserved. The degree of difference observed suggests that the proteins may have subtle or distinct differences in substrate specificity. In other words, they may have different levels of cleavage activity on the cleavage structures of the present invention. When a particular structure is cleaved at a higher rate than the others, this is referred to a preferred substrate, while a structure that is cleaved slowly is considered a less preferred substrate. The designation of preferred or less preferred substrates in this context is not intended to be a limitation of the present invention. It is contemplated that some embodiments of the present invention will make use of the interactions of an enzyme with a less preferred substrate. Candidate enzymes are tested for suitability in the cleavage assays of the present invention using the assays described below.

1. Structure Specific Nuclease Assay

Testing candidate nucleases for structure-specific activities in these assays is done in much the same way as described for testing modified DNA polymerases in Example 2, but with the use of a different library of model structures. In addition to assessing the enzyme performance in primer-independent and primer-directed cleavage, a set of synthetic hairpins are used to examine the length of duplex downstream of the cleavage site preferred by the enzyme.

The FEN-1 and XPG 5' nucleases used in the present invention must be tested for activity in the assays in which they are intended to be used, including but not limited to the

Invader™-directed cleavage detection assay of the present invention and the CFLP® method of characterizing nucleic acids (the CFLP® method is described in co-pending Application Serial Nos. 08/337,164, 08/402,601, 08/484,956 and 08/520,946: the disclosures of these applications are incorporated herein by reference). The Invader™ assay uses a mode of
5 cleavage that has been termed "primer directed" or "primer dependent" to reflect the influence of the an oligonucleotide hybridized to the target nucleic acid upstream of the cleavage site. In contrast, the CFLP® reaction is based on the cleavage of folded structure, or hairpins, within the target nucleic acid, in the absence of any hybridized oligonucleotide. The tests described herein are not intended to be limited to the analysis of nucleases with any particular
10 site of cleavage or mode of recognition of substrate structures. It is contemplated that enzymes may be described as 3' nucleases, utilizing the 3' end as a reference point to recognize structures, or may have a yet a different mode of recognition. Further, the use of the term 5' nucleases is not intended to limit consideration to enzymes that cleave the cleavage structures at any particular site. It refers to a general class of enzymes that require
15 some reference or access to a 5' end to effect cleavage of a structure.

A set of model cleavage structures have been created to allow the cleavage ability of unknown enzymes on such structures to be assessed. Each of the model structures is constructed of one or more synthetic oligonucleotides made by standard DNA synthesis chemistry. Examples of such synthetic model substrate structures are shown in Figs. 26 and
20 60. These are intended only to represent the general folded configuration desirable in such test structures. While a sequence that would assume such a structure is indicated in the figures, there are numerous other sequence arrangements of nucleotides that would be expected to fold in such ways. The essential features to be designed into a set of oligonucleotides to perform the tests described herein are the presence or absence of a
25 sufficiently long 3' arm to allow hybridization of an additional nucleic acid to test cleavage in a "primer-directed" mode, and the length of the duplex region. In the set depicted in Fig. 60, the duplex lengths of the S-33 and the 11-8-0 structures are 12 and 8 basepairs, respectively. This difference in length in the test molecules facilitates detection of discrimination by the candidate nuclease between longer and shorter duplexes. Additions to this series expanding
30 the range of duplex molecules presented to the enzymes, both shorter and longer, may be used. The use of a stabilizing DNA tetraloop [Antao *et al.* (1991) Nucl. Acids Res. 19:5901] or triloop [Hiraro *et al.* (1994) Nuc. Acids Res. 22:576] at the closed end of the duplex helps ensure formation of the expected structure by the oligonucleotide.

The model substrate for testing primer directed cleavage, the "S-60 hairpin" (SEQ ID NO:40) is described in Example 11. In the absence of a primer this hairpin is usually cleaved to release 5' arm fragments of 18 and 19 nucleotides length. An oligonucleotide, termed P-14 (5'-CGAGAGACCACGCT-3'; SEQ ID NO:108), that extends to the base of the duplex when hybridized to the 3' arm of the S-60 hairpin gives cleavage products of the same size, but at a higher rate of cleavage.

To test invasive cleavage a different primer is used, termed P-15 (5'-CGAGAGACCACGCTG-3'; SEQ ID NO:30). In a successful invasive cleavage the presence of this primer shifts the site of cleavage of S-60 into the duplex region, usually releasing products of 21 and 22 nucleotides length.

The S-60 hairpin may also be used to test the effects of modifications of the cleavage structure on either primer-directed or invasive cleavage. Such modifications include, but are not limited to, use of mismatches or base analogs in the hairpin duplex at one, a few or all positions, similar disruptions or modifications in the duplex between the primer and the 3' arm of the S-60, chemical or other modifications to one or both ends of the primer sequence, or attachment of moieties to, or other modifications of the 5' arm of the structure. In all of the analyses using the S-60 or a similar hairpin described herein, activity with and without a primer may be compared using the same hairpin structure.

The assembly of these test reactions, including appropriate amounts of hairpin, primer and candidate nuclease are described in Example 2. As cited therein, the presence of cleavage products is indicated by the presence of molecules which migrate at a lower molecular weight than does the uncleaved test structure. When the reversal of charge of a label is used the products will carry a different net charge than the uncleaved material. Any of these cleavage products indicate that the candidate nuclease has the desired structure-specific nuclease activity. By "desired structure-specific nuclease activity" it is meant only that the candidate nuclease cleaves one or more test molecules. It is not necessary that the candidate nuclease cleave at any particular rate or site of cleavage to be considered successful cleavage.

IX. Signal Enhancement By Completion Of An Activated Protein Binding Site

In addition to the DNA polymerase tailing reaction described above, the present invention also contemplates the use of the products of the invasive cleavage reaction to form activated protein binding sites, such as RNA polymerase promoter duplexes, thereby allowing

the interaction of the completed site to be used as an indicator of the presence of the nucleic acid that is the target of the invasive cleavage reaction. By way of example, when an RNA polymerase promoter duplex is activated by being made complete (*i.e.*, double-stranded over that portion of the promoter region required for polymerase binding) through the hybridization of the oligonucleotide product of the invasive cleavage reaction, the synthesis of RNA can be used as such an indicator.

It is not intended that the transcription reaction of the present invention be limited to the use of any particular RNA polymerase or RNA polymerase promoter region. Promoter sequences are well characterized for several bacteriophage, including bacteriophage SP6, T7 and T3. In addition, promoter sequences have been well characterized for a number of both eukaryotic and prokaryotic RNA polymerases. In a preferred embodiment, the promoter used enables transcription from one of the bacteriophage RNA polymerases. In a particularly preferred embodiment, the promoter used enables transcription by T7 RNA polymerase. Means of performing transcription *in vitro* are well known in the art and commercial kits are available for performing transcription with eukaryotic, prokaryotic or bacteriophage RNA polymerases (*e.g.*, from Promega).

The protein binding regions of the present invention are not limited to the bacteriophage RNA polymerase promoters described above. Other promoter sequences that are contemplated are those of prokaryotes and eukaryotes. For example, many strains of bacteria and fungi are used for the expression of heterologous proteins. The minimal promoters required for transcription by the RNA polymerases of organisms such as yeast and other fungi, eubacteria, nematodes, and cultured mammalian cells are well described in the literature and in the catalogs of commercial suppliers of DNA vectors for the expression of foreign proteins in these organisms.

The binding sites for other types of nucleic acid (*e.g.*, DNA) binding proteins are contemplated for use in the present invention. For example, proteins involved in the regulation of genes exert their effects by binding to the DNA in the vicinity of the promoter from which the RNA from that gene is transcribed. The *lac* operator of *E. coli* is one example of a particularly well characterized and commonly used gene regulation system in which the *lac* repressor protein binds to specific sequences that overlap, and thus block, the promoter for the genes under the repressor's control [Jacob and Monod (1961) Cold Spring Harbor Symposium on Quantitative Biol. XXVI:193-211]. Many similar systems have been described in bacteria, including the *trp* and *AraC* regulatory systems. Given the large amount

of information available about bacterial promoters, the steps described below for the design of suitable partial promoters for the bacteriophage RNA polymerases can be readily adapted to the design of detection systems based on these other promoters.

As noted above, many of the bacterial promoters are under the control of a repressor
5 or other regulatory protein. It is considered to be within the scope of the present invention to include the creation of composite binding sites for these regulatory proteins through the provision of a nucleic acid fragment (*e.g.*, a non-target cleavage product generated in an invasive cleavage reaction). The binding of the regulatory protein to the completed protein binding region (*e.g.*, the composite binding region) can be assessed by any one of a number
10 of means, including slowed electrophoretic migration of either the protein or the DNA fragment, or by a conformational change in the protein or DNA upon binding. In addition, transcription from a downstream promoter can be monitored for up- or down-regulation as a result of the binding of the regulatory protein to the completed protein binding region.

In addition to the bacterial systems described above, many genes in eukaryotic systems
15 have also been found to be under the control of specific proteins that bind to specific regions of duplex DNA. Examples include, but are not limited to, the OCT-1, OCT-2 and AP-4 proteins in mammals and the GAL4 and GCN4 proteins in yeast. Such regulatory proteins usually have a structural motif associated with duplex nucleic acid binding, such as a helix-turn-helix, a zinc finger or a leucine zipper [for review, *see*, Molecular and Cellular Biology
20 (1993) S.L. Wolfe, Ed., Wadsworth Publishing Co., Belmont, CA, pp. 694-715].

For simplicity the test reaction described here will refer to T7 RNA polymerase, and its promoter. This is not intended to limit the invention to the use of this RNA polymerase, and those skilled in the art of molecular biology would be able to readily adapt this described test to the examination of any of the DNA binding proteins, RNA polymerases and their
25 binding or promoter sites discussed above.

It is known in the art that active T7 promoters can be formed by the hybridization of two oligonucleotides, each comprising either the top or bottom strand of the promoter sequence, such that a complete un-nicked duplex promoter is formed [J.F. Milligan, D.R. Groebe, G.W. Witherall, O.C. Uhlenbeck, Nucl. Acids Res. 15:21, 8783-8798 (1987)]. We
30 show here that one way of making the initiation of transcription dependent on the products of an invasive cleavage reaction is to design the probe for the cleavage reaction such that a portion of an RNA polymerase promoter is released as product. The remaining DNA piece or pieces required to assemble a promoter duplex may either be provided as elements in the

reaction mixture, or they may be produced by other invasive cleavage events. If the oligonucleotide pieces are designed to comprise appropriate regions of complementarity they may base pair to form a complete promoter duplex composed of three or more nucleic acid fragments, as depicted in Fig. 88B. A promoter assembled in this way will have nicks in the backbone of one or both strands. In one embodiment, these nicks may be covalently closed through the use of a DNA ligase enzyme. In a preferred embodiment, the nicks are positioned such that transcription can proceed without ligation. In selecting the site of a nick created by the assembly of the partial promoter fragment, at least one nick should be within the recognized promoter region for the RNA polymerase to be used. When a bacteriophage promoter is used, a nick should be between nucleotides -17 and -1, measured from the site of transcription initiation at +1. In a preferred embodiment, a nick will be between nucleotides -13 and -8. In a particularly preferred embodiment, a nick will be between nucleotides -12 and -10 on the non-template strand of the bacteriophage promoter.

When nicks are to be left unrepaired (*i.e.*, not covalently closed with a DNA ligase) it is important to assess the effect of the nick location on the level of transcription from the assembled promoter. A simple test is to combine the oligonucleotides that comprise the separate portions of the promoter with an oligonucleotide that comprises one entire strand of the promoter to be assembled, thereby forming a duplex promoter with a nick in one strand. If the nick is in the top, or non-template strand of the promoter, then the oligonucleotide that comprises the complete promoter is made to include additional non-promoter sequence on its 5' end to serve as a template to be copied in the transcription. This arrangement is depicted in Fig. 88B. Alternatively, if the nick is to be in the bottom, or template strand of the promoter, then the partial promoter oligonucleotide that covers the +1 position, the transcription start site, will include the additional template sequence. This arrangement is depicted in Figs. 95A-D (this figure shows several different embodiments in which a cut probe or non-target cleavage product is used to form a composite promoter which contains one or more nicks on the template strand). In either case, the separate oligonucleotides are combined to form the complete promoter, and the assembly is used in a transcription reaction to create RNA.

To measure the effect of the nick, a substantially identical promoter fragment is created by hybridization of two oligonucleotides that each comprise one strand of the full-length promoter to create an un-nicked version of the same promoter. These two molecular assemblies are tested in parallel transcription reactions and the amount of the

expected RNA that is produced in each reaction is measured for both size and yield. A preferred method of assessing the size of the RNA is by electrophoresis with subsequent visualization. If a labeled nucleotide (e.g., ³²P- GTP, or fluorescein-UTP) is used in the transcription, the RNA can be detected and quantitated by autoradiography, fluorescence
5 imaging or by transfer to support membrane with subsequent detection, e.g., by antibody or hybridization probing. Alternatively, if unlabeled RNA is produced the amounts may be determined by other methods known in the art, such as by spectrophotometry or by electrophoresis with subsequent staining and comparison to known standards.

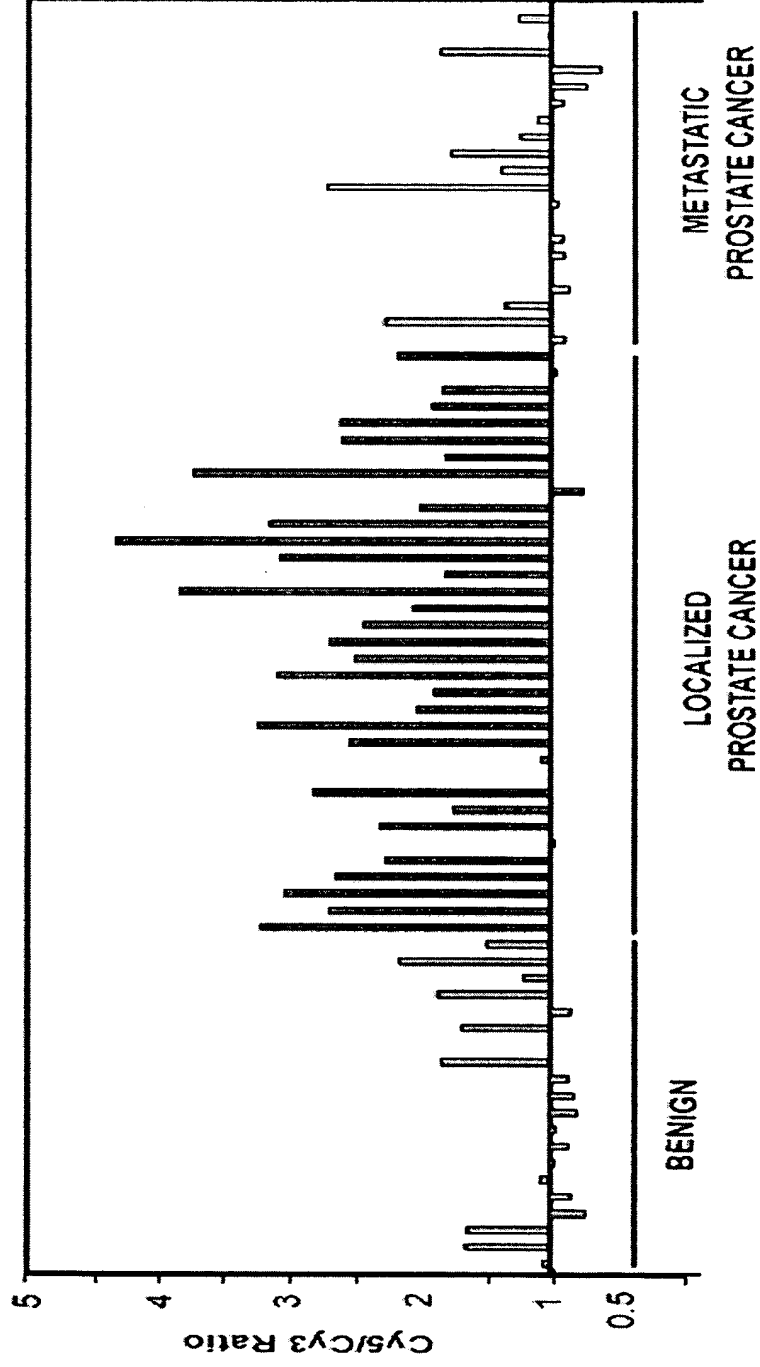
If the size of the RNA is as predicted by the template sequence, or if it matches that
10 produced from the control promoter, it can be presumed to have initiated transcription at the same site in the complex, and to have produced essentially the same RNA product. If the product is much shorter then transcription is either initiating at an internal site or is terminating prematurely [E.T. Schenborn and R.C. Mierendorf, Jr., Nucl. Acids Res. 13:17, 6223 (1985); Milligan *et al.*, *supra*]. While this does not indicate that the assembly tested is
15 completely unsuitable for the assay, the partial transcripts will reduce the gross amount of RNA created, perhaps compromising the signal from the assay, and such products would require further characterization (e.g., finger printing or sequencing) to identify the nucleotide content of the product. It is preferred that the size of the RNA produced matches that of the RNA produced in the control reaction.

20 The yield of the reaction is also examined. It is not necessary that the level of transcription matches that of the control reaction. In some instances (see Ex. 41, below) the nicked promoter may have an enhanced rate of transcription, while in other arrangements transcription may be reduced (relative to the rate from the un-nicked promoter assembly). It is only required that the amount of product be within the detection limits of the method to be
25 used with the test promoter.

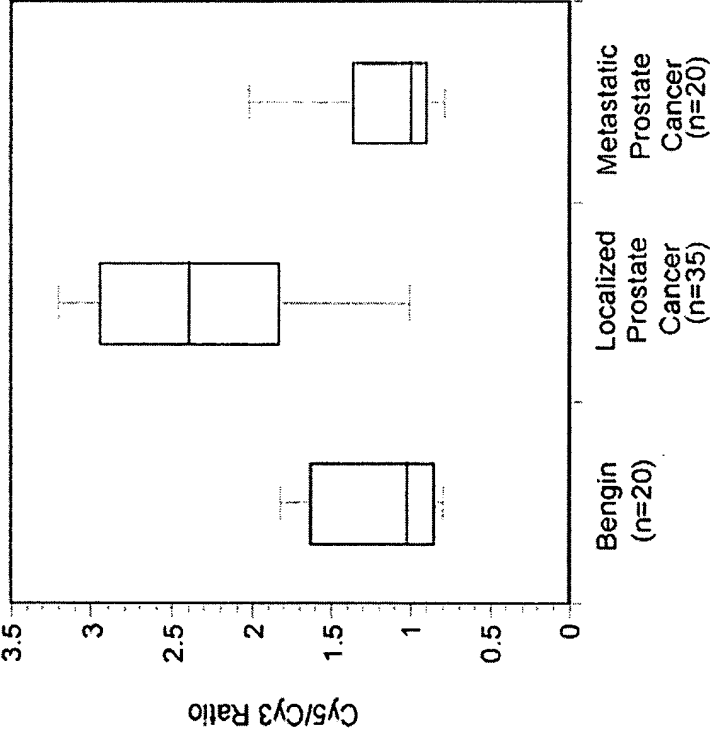
It is reported that transcription from a bacteriophage promoter can produce 200 to 1000 copies of each transcription template (template plus active promoter) in a reaction. These levels of transcription are not required by the present invention. Reactions in which one RNA is produced for each template are also contemplated.

30 The test described above will allow a promoter with a nick in any position to be assessed for utility in this assay. It is an objective of this invention to provide one or more of the oligos which comprise a partial promoter region through invasive cleavage event(s). In this embodiment, the partial promoter sequences are attached to the probe oligonucleotide in

Up-regulation of GP73 in Prostate Cancer Unraveled by DNA Microarray Studies

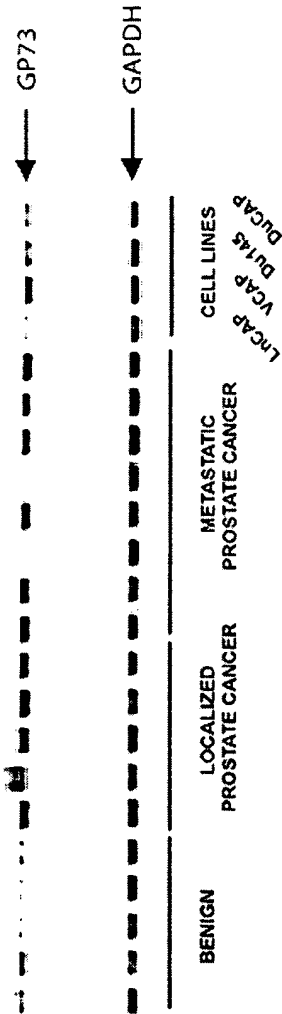


Range of Expression of GP73 In Different
Groups of Prostate Tissue



Tissue Type

Validation of GP73 Messenger RNA Transcript in
Prostate Tissue Samples



the invasive cleavage assay, and are released by cleavage at specific site, as directed by the Invader™ oligonucleotide. It is also intended that transcription be very poor or nonexistent in the absence of the correctly cleaved probe. To assess the success of any oligonucleotide design at meeting these objectives, several transcription reaction tests can be performed.

5 For a promoter assembly that will have a nick on the non-template strand, several partial assemblies that should be tested are shown in Figs. 86 A-D. By way of example, but not by way of limitation, this figure depicts the tests for a nicked promoter in which the upstream, or 5' portion of the non-template strand is to be provided by the invasive cleavage assay. This fragment is seen in Fig. 86A labeled as "cut probe". Transcription reactions
10 incubated in the presence of the duplex shown in Fig. 86A will test the ability of the upstream partial promoter to allow initiation of transcription when hybridized to a bottom strand, termed a "copy template." Similarly, a reaction performed in the presence of the duplex depicted in Fig. 86B will test the ability of the partial promoter fragment nearest the initiation site (the +1 site, as indicated in Fig. 85B) to support transcription of the copy template. It is
15 an important feature of the present invention that neither of these partial promoter duplexes be able to support transcription at the same level as would be seen in transcription from an intact promoter as depicted in Fig. 85B. It is preferred that neither of these partial promoters be sufficient to initiate detectable transcription in the time course of an average transcription reaction, *i.e.*, within about an hour of incubation.

20 Figs. 86C and 86D depict two other duplex arrangements designed to test the effect of uncut probe within the transcription reaction. Fig. 86C depicts the duplex formed between only the uncut probe and the copy template, while Fig. 86D includes the other portion of the promoter. The 3' region of the probe is not complementary to the promoter sequence and therefore produces an unpaired branch in the middle of the promoter. It is an important
25 feature of the present invention that neither of these branched promoter duplexes be able to support transcription at the same level as would be seen in transcription from an intact promoter as depicted in Fig. 85B. It is preferred that neither of these branched promoters be sufficient to initiate detectable transcription in the time course of an average transcription reaction, *i.e.*, within about an hour of incubation.

30 In one embodiment of the transcription system of the present invention, the initiation of transcription from the copy template in the absence of a complete promoter, or in the presence of a branched promoter, is prevented by the judicious placement of the nick or nicks in the composite promoter. For example, as shown in the examples below, placement of a

nick between the -12 and -11 nucleotides of the non-template strand of the bacteriophage T7 promoter allows transcription to take place only when the probe has been successfully cut, as in an invasive cleavage reaction. However, in some instances where the invasive cleavage reaction is to provide the upstream portion of the non-template strand of the promoter (*e.g.*, as depicted in Fig. 88B) it may be necessary or desirable to place the nick on that strand in a particular position for reasons other than providing an optimal composite promoter (*i.e.*, one that is inactive in the absence of any one of the promoter pieces). It may be necessary or desirable to place the nick in such a way that the creation of a branched complete promoter (Fig. 86D) has an undesirable level of transcription, reducing dependence of RNA production on the success of the invasive cleavage step. It is shown in the examples below that transcription from such a branched promoter can be suppressed by a modification of the downstream non-template promoter piece, shown as the "Partial Promoter Oligonucleotide" in Figs. 86, 88, 90 and 95D. As depicted in Fig. 90, the partial promoter oligonucleotide can be provided with a 5' "tail" of nucleotides that are not complementary to the template strand of the promoter, but which are complementary to the 3' portion of the probe oligonucleotide that would be removed in the invasive cleavage reaction. When uncut probe hybridizes to the copy template with the bound 5' tailed partial promoter oligonucleotide, the 5' tail can basepair to the 3' region of the probe, forming a three-way junction as depicted in Fig. 90A. This can effectively shut off transcription, as shown below. When a cut probe hybridizes, as shown in Fig. 90B, a promoter with a small branch is formed, and it is shown herein that such a branched promoter can initiate transcription. Furthermore, if care is taken in selecting the sequence of the 5' tail (*i.e.*, if the first unpaired base is the same nucleotide at the 3' nucleotide of the cut probe, so that they compete for hybridization to the same template strand base), the resulting branched structure may also be cleaved by one of the structure specific nucleases of the present invention, creating the un-branched promoter depicted in Fig. 90C, in some instances enhancing transcription over that seen with the Fig. 90B promoter.

The promoter duplex that is intended to be created, in this embodiment, by the successful execution of the Invader™ directed cleavage assay will include both the "cut probe" and the partial promoter oligonucleotide depicted in Figs. 86A and B, aligned on a single copy template nucleic acid. The testing of the efficiency of transcription of such a nicked promoter segment in comparison to the intact promoter is described above. All of the oligonucleotides described for these test molecules may be created using standard synthesis chemistries.

The set of test molecules depicted in Fig. 86 is designed to assess the transcription capabilities of the variety of structures that may be present in reactions in which the 5' portion of the non-template strand of the promoter is to be supplied by the invader directed cleavage. It is also envisioned that a different portion of partial promoter may be supplied by the invasive cleavage reaction, *e.g.*, the downstream segment of the non-template strand of the promoter, as is shown in Fig. 94. Portions of the template strand of the promoter may also be provided by the cut probe, as shown in Figures 95A-D. An analogous set of test molecules, including "cut" and uncut versions of the probe to be used in the invasive cleavage assay may be created to test any alternative design, whether the nick is to be located on the template or non template strand of the promoter.

The transcription-based visualization methods of the present invention may also be used in a multiplex fashion. Reactions can be constructed such that the presence of one particular target leads to transcription from one type of promoter, while the presence of a different target sequence (*e.g.*, a mutant or variant) or another target suspected of being present, may lead to transcription from a different (*i.e.*, a second) type of promoter. In such an embodiment, the identity of the promoter from which transcription was initiated could be deduced from the type or size of the RNA produced.

By way of example, but not by way of limitation, the bacteriophage promoters can be compared with such an application in view. The promoters for the phage T7, T3 and SP6 are quite similar, each being about 15 to 20 basepairs long, and sharing about 45% identity between -17 and -1 nucleotides, relative to the start of transcription. Despite these similarities, the RNA polymerases from these phage are highly specific for their cognate promoters, such that the other promoters may be present in a reaction, but will not be transcribed [Chamberlin and Ryan (1982) *The Enzymes* XV:87-108]. Because these promoters are similar in size and in the way in which they are recognized by their polymerases [Li *et al.* (1996) *Biochem.* 35:3722] similar nicked versions of the promoters may be designed for use in the methods of the present invention by analogy to the examples described herein which employ the T7 promoter. Because of the high degree of specificity of the RNA polymerases, these nicked promoters may be used together to detect multiple targets in a single reaction. There are many instances in which it would be highly desirable to detect multiple nucleic acid targets in a single sample, including cases in which multiple infectious agents may be present, or in which variants of a single type of target may need to be identified. Alternatively, it is often desirable to use a combination of probes to detect both a

target sequence and an internal control sequence, to gauge the effects of sample contaminants on the output of the assay. The use of multiple promoters allows the reaction to be assessed for both the efficiency of the invasive cleavage and the robustness of the transcription.

As stated above, the phage promoters were described in detail as an example of suitable protein binding regions (*e.g.*, which can be used to generate a composite promoter) for use in the methods of the present invention. The invention is not limited to the use of phage RNA polymerase promoter regions, in particular, and RNA polymerase promoter regions, in general. Suitably specific, well characterized promoters are also found in both prokaryotic and eukaryotic systems.

The RNA that is produced in a manner that is dependent of the successful detection of the target nucleic acid in the invasive cleavage reaction may be detected in any of several ways. If a labeled nucleotide is incorporated into the RNA during transcription, the RNA may be detected directly after fractionation, *e.g.*, by electrophoresis or chromatography. The labeled RNA may also be captured onto a solid support, such as a microtitre plate, a bead or a dipstick, *e.g.*, by hybridization, antibody capture, or through an affinity interaction such as that between biotin and avidin. Capture may facilitate the measuring of incorporated label, or it may be an intermediate step before probe hybridization or similar detection means. If the maximum amount of label is desired to be incorporated into each transcript, it is preferred that the copy template be very long, around 3 to 10 kilobases, so that each RNA molecule will carry many labels. Alternatively, it may be desired that a single site or a limited number of sites within the transcript be specifically labeled. In this case, it may be desirable to have a short copy template with only one or a few residues that would allow incorporation of the labeled nucleotide.

The copy template may also be selected to produce RNAs that perform specified functions. In a simple case, if an duplex-dependent intercalating fluorophore is to be used to detect the RNA product, it may be desirable to transcribe an RNA that is known to form duplexed secondary structures, such as a ribosomal RNA or a tRNA. In another embodiment, the RNA may be designed to interact specifically, or with particular affinity, with a different substance. It has been shown that a process of alternating steps of selection (*e.g.*, by binding to a target substance) and *in vitro* amplification (*e.g.*, by PCR) can be used to identify nucleic acid ligands with novel and useful properties [Tuerk and Gold (1990) Science 249:505]. This system has been used to identify RNAs, termed ligands or aptamers, that bind tightly and specifically to proteins and to other types of molecules, such as antibiotics [Wang et al.

(1996) Biochem. 35:12338] and hormones. RNAs can even be selected to bind to other RNAs through non-Watson-Crick interactions [Schmidt *et al.* (1996) Ann. N.Y. Acad. Sci. 782:526]. A ligand RNA may be used to either inactivate or enhance the activity of a molecule to which it binds. Any RNA segment identified through such a process may also be produced by the methods of the present invention, so that the observation of the activity of the RNA ligand may be used as a specific sign of the presence of the target material in the invasive cleavage reaction. The ligand binding to its specific partner may also be used as another way of capturing a readout signal to a solid support.

The product RNA might also be designed to have a catalytic function, *e.g.*, to act as a ribozyme, allowing cleavage another molecule to be indicative of the success of the primary invasive cleavage reaction [Uhlenbeck (1987) Nature 328:596]. In yet another embodiment, the RNA may be made to encode a peptide sequence. When coupled to an *in vitro* translation system (*e.g.*, the S-30 system derived from *E. coli* [Lesley (1985) Methods Mol. Biol. 37:265] or a rabbit reticulocyte lysate system [Dasso and Jackson (1989) Nucleic Acids Res. 17:3129], available from Promega), the production of the appropriate protein may be detected. In a preferred embodiment, the proteins produced include those that allow either colorimetric or luminescent detection, such as beta-galactosidase (lac-Z) or luciferase, respectively.

The above discussion focused on the use of the present transcription visualization methods in the context of the Invader™-directed cleavage assay (*i.e.*, the non-target cleavage products produced in the Invader™ assay were used to complete and activate a protein binding region, such as a promoter region). However, the transcription visualization methods are not limited to this context. Any assay which produces an oligonucleotide product having relatively discrete ends can be used in conjunction with the present transcription visualization methods. For example, the homogenous assay described in U.S. Patent No. 5,210,015, particularly when conducted under conditions where polymerization cannot occur, produces short oligonucleotide fragments as the result of cleavage of a probe. If this assay is conducted under conditions where polymerase occurs, the site of cleavage of the probe may be focused through the use of nucleotide analogs that have uncleavable linkages at particular positions within the probe. These short oligonucleotides can be employed in a manner analogous to the cut probe or non-target cleavage products produced in the invasive cleavage reactions of the present invention. Additional assays which generate suitable oligonucleotide products are known to the art. For example, the non-target cleavage products produced in assays such as the "Cycling Probe Reaction" (Duck *et al.*, BioTech., 9:142 [1990] and U.S.

Patents Nos. 4,876,187 and 5,011,769), in which shorter oligonucleotides are released from longer oligonucleotides after hybridization to a target sequence would be suitable, as would short restriction fragments released in assays where a probe is designed to be cleaved when successfully hybridized to an appropriate restriction recognition sequence (U.S. Patent No. 4,683,194).

Assays which generate short oligonucleotides having "ragged" (*i.e.*, not discrete) 3' ends can also be employed with success in the transcription reactions of the present invention when the oligonucleotide provided by this non-transcription reaction are used to provide a portion of the promoter region located downstream of the other oligonucleotide(s) which are required to complete the promoter region (that is a 3' tail or unpaired extension can be tolerated when the oligo is being used as the "Cut Probe" is in Figs. 94 and 95A).

EXPERIMENTAL

The following examples serve to illustrate certain preferred embodiments and aspects of the present invention and are not to be construed as limiting the scope thereof.

In the disclosure which follows, the following abbreviations apply: °C (degrees Centigrade); fig (figure); g (gravitational field); hr (hour); min (minute); oligo (oligonucleotide); rxn (reaction); vol (volume); w/v (weight to volume); v/v (volume to volume); BSA (bovine serum albumin); CTAB (cetyltrimethylammonium bromide); HPLC (high pressure liquid chromatography); DNA (deoxyribonucleic acid); p (plasmid); µl (microliters); ml (milliliters); µg (micrograms); pmoles (picomoles); mg (milligrams); M (molar); mM (milliMolar); µM (microMolar); nm (nanometers); kdal (kilodaltons); OD (optical density); EDTA (ethylene diamine tetra-acetic acid); FITC (fluorescein isothiocyanate); SDS (sodium dodecyl sulfate); NaPO₄ (sodium phosphate); NP-40 (Nonidet P-40); Tris (tris(hydroxymethyl)-aminomethane); PMSF (phenylmethylsulfonylfluoride); TBE (Tris-Borate-EDTA, *i.e.*, Tris buffer titrated with boric acid rather than HCl and containing EDTA); PBS (phosphate buffered saline); PPBS (phosphate buffered saline containing 1 mM PMSF); PAGE (polyacrylamide gel electrophoresis); Tween (polyoxyethylene-sorbitan); Ambion (Ambion, Inc., Austin, TX); Boehringer (Boehringer Mannheim Biochemical, Indianapolis, IN); Dynal (Dynal A.S., Oslo, Norway); Epicentre (Epicentre Technologies, Madison, WI); MJ Research (MJ Research, Watertown, MA); National Biosciences (Plymouth,

MN); New England Biolabs (Beverly, MA); Novagen (Novagen, Inc., Madison, WI); Perkin Elmer (Norwalk, CT); Promega (Promega Corp., Madison, WI); Stratagene (Stratagene Cloning Systems, La Jolla, CA); USB (U.S. Biochemical, Cleveland, OH).

5

EXAMPLE 1

Characteristics Of Native Thermostable DNA Polymerases

A. 5' Nuclease Activity Of DNAP_{Taq}

During the polymerase chain reaction (PCR) [Saiki *et al.*, *Science* 239:487 (1988); Mullis and Faloona, *Methods in Enzymology* 155:335 (1987)], DNAP_{Taq} is able to amplify
10 many, but not all, DNA sequences. One sequence that cannot be amplified using DNAP_{Taq} is shown in Fig. 5 (Hairpin structure is SEQ ID NO:15. Fig. 5 also shows a primer: SEQ ID NO:17.) This DNA sequence has the distinguishing characteristic of being able to fold on
15 itself to form a hairpin with two single-stranded arms, which correspond to the primers used in PCR.

To test whether this failure to amplify is due to the 5' nuclease activity of the enzyme, we compared the abilities of DNAP_{Taq} and DNAP_{Stf} to amplify this DNA sequence during 30 cycles of PCR. Synthetic oligonucleotides were obtained from The Biotechnology Center at the University of Wisconsin-Madison. The DNAP_{Taq} and DNAP_{Stf} were from Perkin
20 Elmer (*i.e.*, AmplitaqTM DNA polymerase and the Stoffel fragment of AmplitaqTM DNA polymerase). The substrate DNA comprised the hairpin structure shown in Fig. 6 cloned in a double-stranded form into pUC19. The primers used in the amplification are listed as SEQ ID NOS:16-17. Primer SEQ ID NO:17 is shown annealed to the 3' arm of the hairpin structure in Fig. 5. Primer SEQ ID NO:16 is shown as the first 20 nucleotides in bold on the
25 5' arm of the hairpin in Fig. 5.

Polymerase chain reactions comprised 1 ng of supercoiled plasmid target DNA, 5 pmoles of each primer, 40 μ M each dNTP, and 2.5 units of DNAP_{Taq} or DNAP_{Stf}, in a 50 μ l solution of 10 mM Tris•Cl pH 8.3. The DNAP_{Taq} reactions included 50 mM KCl and 1.5 mM MgCl₂. The temperature profile was 95°C for 30 sec., 55°C for 1 min. and 72°C for 1
30 min., through 30 cycles. Ten percent of each reaction was analyzed by gel electrophoresis through 6% polyacrylamide (cross-linked 29:1) in a buffer of 45 mM Tris•Borate, pH 8.3, 1.4 mM EDTA.

The results are shown in Fig. 6. The expected product was made by DNAPStf (indicated simply as "S") but not by DNAP*Taq* (indicated as "T"). We conclude that the 5' nuclease activity of DNAP*Taq* is responsible for the lack of amplification of this DNA sequence.

5 To test whether the 5' unpaired nucleotides in the substrate region of this structured DNA are removed by DNAP*Taq*, the fate of the end-labeled 5' arm during four cycles of PCR was compared using the same two polymerases (Fig. 7). The hairpin templates, such as the one described in Fig. 5, were made using DNAPStf and a ³²P-5'-end-labeled primer. The 5'-end of the DNA was released as a few large fragments by DNAP*Taq* but not by DNAPStf.
10 The sizes of these fragments (based on their mobilities) show that they contain most or all of the unpaired 5' arm of the DNA. Thus, cleavage occurs at or near the base of the bifurcated duplex. These released fragments terminate with 3' OH groups, as evidenced by direct sequence analysis, and the abilities of the fragments to be extended by terminal deoxynucleotidyl transferase.

15 Figs. 8-10 show the results of experiments designed to characterize the cleavage reaction catalyzed by DNAP*Taq*. Unless otherwise specified, the cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled hairpin DNA (with the unlabeled complementary strand also present), 1 pmole primer (complementary to the 3' arm) and 0.5 units of DNAP*Taq* (estimated to be 0.026 pmoles) in a total volume of 10 µl of 10 mM Tris-
20 Cl, pH 8.5, 50 mM KCl and 1.5 mM MgCl₂. As indicated, some reactions had different concentrations of KCl, and the precise times and temperatures used in each experiment are indicated in the individual figures. The reactions that included a primer used the one shown in Fig. 5 (SEQ ID NO:17). In some instances, the primer was extended to the junction site by providing polymerase and selected nucleotides.

25 Reactions were initiated at the final reaction temperature by the addition of either the MgCl₂ or enzyme. Reactions were stopped at their incubation temperatures by the addition of 8 µl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. The T_m calculations listed were made using the Oligo™ primer analysis software from National Biosciences, Inc. These were determined using 0.25 µM as the DNA concentration, at either 15 or 65 mM total
30 salt (the 1.5 mM MgCl₂ in all reactions was given the value of 15 mM salt for these calculations).

Fig. 8 is an autoradiogram containing the results of a set of experiments and conditions on the cleavage site. Fig. 8A is a determination of reaction components that enable cleavage.

Incubation of 5'-end-labeled hairpin DNA was for 30 minutes at 55°C. with the indicated components. The products were resolved by denaturing polyacrylamide gel electrophoresis and the lengths of the products, in nucleotides, are indicated. Fig. 8B describes the effect of temperature on the site of cleavage in the absence of added primer. Reactions were incubated in the absence of KCl for 10 minutes at the indicated temperatures. The lengths of the products, in nucleotides, are indicated.

Surprisingly, cleavage by DNAPTag requires neither a primer nor dNTPs (*see* Fig. 8A). Thus, the 5' nuclease activity can be uncoupled from polymerization. Nuclease activity requires magnesium ions, though manganese ions can be substituted, albeit with potential changes in specificity and activity. Neither zinc nor calcium ions support the cleavage reaction. The reaction occurs over a broad temperature range, from 25°C to 85°C, with the rate of cleavage increasing at higher temperatures.

Still referring to Fig. 8, the primer is not elongated in the absence of added dNTPs. However, the primer influences both the site and the rate of cleavage of the hairpin. The change in the site of cleavage (Fig. 8A) apparently results from disruption of a short duplex formed between the arms of the DNA substrate. In the absence of primer, the sequences indicated by underlining in Fig. 5 could pair, forming an extended duplex. Cleavage at the end of the extended duplex would release the 11 nucleotide fragment seen on the Fig. 8A lanes with no added primer. Addition of excess primer (Fig. 8A, lanes 3 and 4) or incubation at an elevated temperature (Fig. 8B) disrupts the short extension of the duplex and results in a longer 5' arm and, hence, longer cleavage products.

The location of the 3' end of the primer can influence the precise site of cleavage. Electrophoretic analysis revealed that in the absence of primer (Fig. 8B), cleavage occurs at the end of the substrate duplex (either the extended or shortened form, depending on the temperature) between the first and second base pairs. When the primer extends up to the base of the duplex, cleavage also occurs one nucleotide into the duplex. However, when a gap of four or six nucleotides exists between the 3' end of the primer and the substrate duplex, the cleavage site is shifted four to six nucleotides in the 5' direction.

Fig. 9 describes the kinetics of cleavage in the presence (Fig. 9A) or absence (Fig. 9B) of a primer oligonucleotide. The reactions were run at 55°C with either 50 mM KCl (Fig. 9A) or 20 mM KCl (Fig. 9B). The reaction products were resolved by denaturing polyacrylamide gel electrophoresis and the lengths of the products, in nucleotides, are indicated. "M", indicating a marker, is a 5' end-labeled 19-nt oligonucleotide. Under these

salt conditions, Figs. 9A and 9B indicate that the reaction appears to be about twenty times faster in the presence of primer than in the absence of primer. This effect on the efficiency may be attributable to proper alignment and stabilization of the enzyme on the substrate.

5 The relative influence of primer on cleavage rates becomes much greater when both reactions are run in 50 mM KCl. In the presence of primer, the rate of cleavage increases with KCl concentration, up to about 50 mM. However, inhibition of this reaction in the presence of primer is apparent at 100 mM and is complete at 150 mM KCl. In contrast, in the absence of primer the rate is enhanced by concentration of KCl up to 20 mM, but it is reduced at concentrations above 30 mM. At 50 mM KCl, the reaction is almost completely
10 inhibited. The inhibition of cleavage by KCl in the absence of primer is affected by temperature, being more pronounced at lower temperatures.

Recognition of the 5' end of the arm to be cut appears to be an important feature of substrate recognition. Substrates that lack a free 5' end, such as circular M13 DNA, cannot be cleaved under any conditions tested. Even with substrates having defined 5' arms, the rate
15 of cleavage by DNAP*Taq* is influenced by the length of the arm. In the presence of primer and 50 mM KCl, cleavage of a 5' extension that is 27 nucleotides long is essentially complete within 2 minutes at 55°C. In contrast, cleavages of molecules with 5' arms of 84 and 188 nucleotides are only about 90% and 40% complete after 20 minutes. Incubation at higher temperatures reduces the inhibitory effects of long extensions indicating that secondary
20 structure in the 5' arm or a heat-labile structure in the enzyme may inhibit the reaction. A mixing experiment, run under conditions of substrate excess, shows that the molecules with long arms do not preferentially tie up the available enzyme in non-productive complexes. These results may indicate that the 5' nuclease domain gains access to the cleavage site at the end of the bifurcated duplex by moving down the 5' arm from one end to the other. Longer
25 5' arms would be expected to have more adventitious secondary structures (particularly when KCl concentrations are high), which would be likely to impede this movement.

Cleavage does not appear to be inhibited by long 3' arms of either the substrate strand target molecule or pilot nucleic acid, at least up to 2 kilobases. At the other extreme, 3' arms of the pilot nucleic acid as short as one nucleotide can support cleavage in a primer-
30 independent reaction, albeit inefficiently. Fully paired oligonucleotides do not elicit cleavage of DNA templates during primer extension.

The ability of DNAP*Taq* to cleave molecules even when the complementary strand contains only one unpaired 3' nucleotide may be useful in optimizing allele-specific PCR.

PCR primers that have unpaired 3' ends could act as pilot oligonucleotides to direct selective cleavage of unwanted templates during preincubation of potential template-primer complexes with DNAP Taq in the absence of nucleoside triphosphates.

5 **B. 5' Nuclease Activities Of Other DNAPs**

To determine whether other 5' nucleases in other DNAPs would be suitable for the present invention, an array of enzymes, several of which were reported in the literature to be free of apparent 5' nuclease activity, were examined. The ability of these other enzymes to cleave nucleic acids in a structure-specific manner was tested using the hairpin substrate
10 shown in Fig. 5 under conditions reported to be optimal for synthesis by each enzyme.

DNAPEcl and DNAP Klenow were obtained from Promega Corporation; the DNAP of *Pyrococcus furiosus* ["Pfu", Bargseid *et al.*, Strategies 4:34 (1991)] was from Stratagene; the DNAP of *Thermococcus litoralis* ["Tli", VentTM(exo-), Perler *et al.*, Proc. Natl. Acad. Sci. USA 89:5577 (1992)] was from New England Biolabs; the DNAP of *Thermus flavus* ["Tfl",
15 Kaledin *et al.*, Biokhimiya 46:1576 (1981)] was from Epicentre Technologies; and the DNAP of *Thermus thermophilus* ["Tth", Carballeira *et al.*, Biotechniques 9:276 (1990); Myers *et al.*, Biochem. 30:7661 (1991)] was from U.S. Biochemicals.

0.5 units of each DNA polymerase was assayed in a 20 μ l reaction, using either the buffers supplied by the manufacturers for the primer-dependent reactions, or 10 mM Tris•Cl,
20 pH 8.5, 1.5 mM MgCl₂, and 20mM KCl. Reaction mixtures were at held 72°C before the addition of enzyme.

Fig. 10 is an autoradiogram recording the results of these tests. Fig. 10A demonstrates reactions of endonucleases of DNAPs of several thermophilic bacteria. The reactions were incubated at 55°C for 10 minutes in the presence of primer or at 72°C for 30 minutes in the
25 absence of primer, and the products were resolved by denaturing polyacrylamide gel electrophoresis. The lengths of the products, in nucleotides, are indicated. Fig. 10B demonstrates endonucleolytic cleavage by the 5' nuclease of DNAPEcl. The DNAPEcl and DNAP Klenow reactions were incubated for 5 minutes at 37°C. Note the light band of cleavage products of 25 and 11 nucleotides in the DNAPEcl lanes (made in the presence and
30 absence of primer, respectively). Fig. 8A also demonstrates DNAP Taq reactions in the presence (+) or absence (-) of primer. These reactions were run in 50 mM and 20 mM KCl, respectively, and were incubated at 55°C for 10 minutes.

Referring to Fig. 10A. DNAPs from the eubacteria *Thermus thermophilus* and *Thermus flavus* cleave the substrate at the same place as DNAP*Taq*, both in the presence and absence of primer. In contrast, DNAPs from the archaeobacteria *Pyrococcus furiosus* and *Thermococcus litoralis* are unable to cleave the substrates endonucleolytically. The DNAPs from *Pyrococcus furiosus* and *Thermococcus litoralis* share little sequence homology with eubacterial enzymes (Ito *et al.*, *Nucl. Acids Res.* 19:4045 (1991); Mathur *et al.*, *Nucl. Acids Res.* 19:6952 (1991); *see also* Perler *et al.*). Referring to Fig. 10B, DNAPEcl also cleaves the substrate, but the resulting cleavage products are difficult to detect unless the 3' exonuclease is inhibited. The amino acid sequences of the 5' nuclease domains of DNAPEcl and DNAP*Taq* are about 38% homologous (Gelfand, *supra*).

The 5' nuclease domain of DNAP*Taq* also shares about 19% homology with the 5' exonuclease encoded by gene 6 of bacteriophage T7 [Dunn *et al.*, *J. Mol. Biol.* 166:477 (1983)]. This nuclease, which is not covalently attached to a DNAP polymerization domain, is also able to cleave DNA endonucleolytically, at a site similar or identical to the site that is cut by the 5' nucleases described above, in the absence of added primers.

C. Transcleavage

The ability of a 5' nuclease to be directed to cleave efficiently at any specific sequence was demonstrated in the following experiment. A partially complementary oligonucleotide termed a "pilot oligonucleotide" was hybridized to sequences at the desired point of cleavage. The non-complementary part of the pilot oligonucleotide provided a structure analogous to the 3' arm of the template (*see* Fig. 5), whereas the 5' region of the substrate strand became the 5' arm. A primer was provided by designing the 3' region of the pilot so that it would fold on itself creating a short hairpin with a stabilizing tetra-loop [Antao *et al.*, *Nucl. Acids Res.* 19:5901 (1991)]. Two pilot oligonucleotides are shown in Fig. 11A. Oligonucleotides 19-12 (SEQ ID NO:18), 30-12 (SEQ ID NO:19) and 30-0 (SEQ ID NO:20) are 31, 42 or 30 nucleotides long, respectively. However, oligonucleotides 19-12 (SEQ ID NO:18) and 34-19 (SEQ ID NO:19) have only 19 and 30 nucleotides, respectively, that are complementary to different sequences in the substrate strand. The pilot oligonucleotides are calculated to melt off their complements at about 50°C (19-12) and about 75°C (30-12). Both pilots have 12 nucleotides at their 3' ends, which act as 3' arms with base-paired primers attached.

To demonstrate that cleavage could be directed by a pilot oligonucleotide, we incubated a single-stranded target DNA with DNAP*Taq* in the presence of two potential pilot

oligonucleotides. The transcleavage reactions, where the target and pilot nucleic acids are not covalently linked, includes 0.01 pmoles of single end-labeled substrate DNA, 1 unit of DNAP*Taq* and 5 pmoles of pilot oligonucleotide in a volume of 20 μ l of the same buffers. These components were combined during a one minute incubation at 95°C, to denature the
5 PCR-generated double-stranded substrate DNA, and the temperatures of the reactions were then reduced to their final incubation temperatures. Oligonucleotides 30-12 and 19-12 can hybridize to regions of the substrate DNAs that are 85 and 27 nucleotides from the 5' end of the targeted strand.

Fig. 19 shows the complete 206-mer sequence (SEQ ID NO:27). The 206-mer was
10 generated by PCR. The M13/pUC 24-mer reverse sequencing (-48) primer and the M13/pUC sequencing (-47) primer from New England Biolabs (catalogue nos. 1233 and 1224 respectively) were used (50 pmoles each) with the pGEM3z(f+) plasmid vector (Promega Corp.) as template (10 ng) containing the target sequences. The conditions for PCR were as follows: 50 μ M of each dNTP and 2.5 units of *Taq* DNA polymerase in 100 μ l of 20 mM
15 Tris-Cl, pH 8.3, 1.5 mM MgCl₂, 50 mM KCl with 0.05% Tween-20 and 0.05% NP-40. Reactions were cycled 35 times through 95°C for 45 seconds, 63°C for 45 seconds, then 72°C for 75 seconds. After cycling, reactions were finished off with an incubation at 72°C for 5 minutes. The resulting fragment was purified by electrophoresis through a 6% polyacrylamide gel (29:1 cross link) in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM
20 EDTA, visualized by ethidium bromide staining or autoradiography, excised from the gel, eluted by passive diffusion, and concentrated by ethanol precipitation.

Cleavage of the substrate DNA occurred in the presence of the pilot oligonucleotide 19-12 at 50°C (Fig. 11B, lanes 1 and 7) but not at 75°C (lanes 4 and 10). In the presence of oligonucleotide 30-12 cleavage was observed at both temperatures. Cleavage did not occur in
25 the absence of added oligonucleotides (lanes 3, 6 and 12) or at about 80°C even though at 50°C adventitious structures in the substrate allowed primer-independent cleavage in the absence of KCl (Fig. 11B, lane 9). A non-specific oligonucleotide with no complementarity to the substrate DNA did not direct cleavage at 50°C, either in the absence or presence of 50 mM KCl (lanes 13 and 14). Thus, the specificity of the cleavage reactions can be controlled
30 by the extent of complementarity to the substrate and by the conditions of incubation.

D. Cleavage Of RNA

A shortened RNA version of the sequence used in the transcleavage experiments discussed above was tested for its ability to serve as a substrate in the reaction. The RNA is cleaved at the expected place, in a reaction that is dependent upon the presence of the pilot oligonucleotide. The RNA substrate, made by T7 RNA polymerase in the presence of [α -³²P]UTP, corresponds to a truncated version of the DNA substrate used in Fig. 11B. Reaction conditions were similar to those in used for the DNA substrates described above, with 50 mM KCl; incubation was for 40 minutes at 55°C. The pilot oligonucleotide used is termed 30-0 (SEQ ID NO:20) and is shown in Fig. 12A.

The results of the cleavage reaction is shown in Fig. 13B. The reaction was run either in the presence or absence of DNAP*Taq* or pilot oligonucleotide as indicated in Fig. 12B.

Strikingly, in the case of RNA cleavage, a 3' arm is not required for the pilot oligonucleotide. It is very unlikely that this cleavage is due to previously described RNaseH, which would be expected to cut the RNA in several places along the 30 base-pair long RNA-DNA duplex. The 5' nuclease of DNAP*Taq* is a structure-specific RNaseH that cleaves the RNA at a single site near the 5' end of the heteroduplexed region.

It is surprising that an oligonucleotide lacking a 3' arm is able to act as a pilot in directing efficient cleavage of an RNA target because such oligonucleotides are unable to direct efficient cleavage of DNA targets using native DNAPs. However, some 5' nucleases of the present invention (for example, clones E, F and G of Fig. 4) can cleave DNA in the absence of a 3' arm. In other words, a non-extendable cleavage structure is not required for specific cleavage with some 5' nucleases of the present invention derived from thermostable DNA polymerases.

We tested whether cleavage of an RNA template by DNAP*Taq* in the presence of a fully complementary primer could help explain why DNAP*Taq* is unable to extend a DNA oligonucleotide on an RNA template, in a reaction resembling that of reverse transcriptase. Another thermophilic DNAP, DNAP*Tth*, is able to use RNA as a template, but only in the presence of Mn⁺⁺, so we predicted that this enzyme would not cleave RNA in the presence of this cation. Accordingly, we incubated an RNA molecule with an appropriate pilot oligonucleotide in the presence of DNAP*Taq* or DNAP*Tth*, in buffer containing either Mg⁺⁺ or Mn⁺⁺. As expected, both enzymes cleaved the RNA in the presence of Mg⁺⁺. However, DNAP*Taq*, but not DNAP*Tth*, degraded the RNA in the presence of Mn⁺⁺. We conclude

that the 5' nuclease activities of many DNAPs may contribute to their inability to use RNA as templates.

EXAMPLE 2

5 Generation Of 5' Nucleases From Thermostable DNA Polymerases

Thermostable DNA polymerases were generated which have reduced synthetic activity, an activity that is an undesirable side-reaction during DNA cleavage in the detection assay of the invention, yet have maintained thermostable nuclease activity. The result is a
10 thermostable polymerase which cleaves nucleic acids DNA with extreme specificity.

Type A DNA polymerases from eubacteria of the genus *Thermus* share extensive protein sequence identity (90% in the polymerization domain, using the Lipman-Pearson method in the DNA analysis software from DNASTar, WI) and behave similarly in both polymerization and nuclease assays. Therefore, we have used the genes for the DNA
15 polymerase of *Thermus aquaticus* (DNAPTaq) and *Thermus flavus* (DNAPTfl) as representatives of this class. Polymerase genes from other eubacterial organisms, such as *Thermus thermophilus*, *Thermus sp.*, *Thermotoga maritima*, *Thermosipho africanus* and *Bacillus stearothermophilus* are equally suitable. The DNA polymerases from these thermophilic organisms are capable of surviving and performing at elevated temperatures, and
20 can thus be used in reactions in which temperature is used as a selection against non-specific hybridization of nucleic acid strands.

The restriction sites used for deletion mutagenesis, described below, were chosen for convenience. Different sites situated with similar convenience are available in the *Thermus thermophilus* gene and can be used to make similar constructs with other Type A polymerase
25 genes from related organisms.

A. Creation Of 5' Nuclease Constructs

1. Modified DNAPTaq Genes

The first step was to place a modified gene for the *Taq* DNA polymerase on a plasmid
30 under control of an inducible promoter. The modified *Taq* polymerase gene was isolated as follows: The *Taq* DNA polymerase gene was amplified by polymerase chain reaction from genomic DNA from *Thermus aquaticus*, strain YT-1 (Lawyer *et al.*, *supra*), using as primers the oligonucleotides described in SEQ ID NOS:13-14. The resulting fragment of DNA has a

recognition sequence for the restriction endonuclease *EcoRI* at the 5' end of the coding sequence and a *BglII* sequence at the 3' end. Cleavage with *BglII* leaves a 5' overhang or "sticky end" that is compatible with the end generated by *BamHI*. The PCR-amplified DNA was digested with *EcoRI* and *BamHI*. The 2512 bp fragment containing the coding region for the polymerase gene was gel purified and then ligated into a plasmid which contains an inducible promoter.

In one embodiment of the invention, the pTTQ18 vector, which contains the hybrid *irp-lac (tac)* promoter, was used [M.J.R. Stark, *Gene* 5:255 (1987)] and shown in Fig. 13. The *tac* promoter is under the control of the *E. coli lac* repressor. Repression allows the synthesis of the gene product to be suppressed until the desired level of bacterial growth has been achieved, at which point repression is removed by addition of a specific inducer, isopropyl- β -D-thiogalactopyranoside (IPTG). Such a system allows the expression of foreign proteins that may slow or prevent growth of transformants.

Bacterial promoters, such as *tac*, may not be adequately suppressed when they are present on a multiple copy plasmid. If a highly toxic protein is placed under control of such a promoter, the small amount of expression leaking through can be harmful to the bacteria. In another embodiment of the invention, another option for repressing synthesis of a cloned gene product was used. The non-bacterial promoter, from bacteriophage T7, found in the plasmid vector series pET-3 was used to express the cloned mutant *Taq* polymerase genes [Fig. 15; Studier and Moffatt, *J. Mol. Biol.* 189:113 (1986)]. This promoter initiates transcription only by T7 RNA polymerase. In a suitable strain, such as BL21(DE3)pLYS, the gene for this RNA polymerase is carried on the bacterial genome under control of the *lac* operator. This arrangement has the advantage that expression of the multiple copy gene (on the plasmid) is completely dependent on the expression of T7 RNA polymerase, which is easily suppressed because it is present in a single copy.

For ligation into the pTTQ18 vector (Fig. 13), the PCR product DNA containing the *Taq* polymerase coding region (mut*Taq*, clone 4B, SEQ ID NO:21) was digested with *EcoRI* and *BglII* and this fragment was ligated under standard "sticky end" conditions [Sambrook *et al. Molecular Cloning*, Cold Spring Harbor Laboratory Press, Cold Spring Harbor, pp. 1.63-1.69 (1989)] into the *EcoRI* and *BamHI* sites of the plasmid vector pTTQ18. Expression of this construct yields a translational fusion product in which the first two residues of the native protein (Met-Arg) are replaced by three from the vector (Met-Asn-Ser), but the remainder of the natural protein would not change. The construct was transformed into the JM109 strain of

E. coli and the transformants were plated under incompletely repressing conditions that do not permit growth of bacteria expressing the native protein. These plating conditions allow the isolation of genes containing pre-existing mutations, such as those that result from the infidelity of *Taq* polymerase during the amplification process.

5 Using this amplification/selection protocol, we isolated a clone (depicted in Fig. 3B) containing a mutated *Taq* polymerase gene (*mutTaq*, clone 3B). The mutant was first detected by its phenotype, in which temperature-stable 5' nuclease activity in a crude cell extract was normal, but polymerization activity was almost absent (approximately less than 1% of wild type *Taq* polymerase activity).

10 DNA sequence analysis of the recombinant gene showed that it had changes in the polymerase domain resulting in two amino acid substitutions: an A to G change at nucleotide position 1394 causes a Glu to Gly change at amino acid position 465 (numbered according to the natural nucleic and amino acid sequences, SEQ ID NOS:1 and 4) and another A to G change at nucleotide position 2260 causes a Gln to Arg change at amino acid position 754.
15 Because the Gln to Gly mutation is at a nonconserved position and because the Glu to Arg mutation alters an amino acid that is conserved in virtually all of the known Type A polymerases, this latter mutation is most likely the one responsible for curtailing the synthesis activity of this protein. The nucleotide sequence for the Fig. 3B construct is given in SEQ ID NO:21. The enzyme encoded by this sequence is referred to as Cleavase® A/G.

20 Subsequent derivatives of DNAP*Taq* constructs were made from the *mutTaq* gene, thus, they all bear these amino acid substitutions in addition to their other alterations, unless these particular regions were deleted. These mutated sites are indicated by black boxes at these locations in the diagrams in Fig. 3. In Fig. 3, the designation "3' Exo" is used to indicate the location of the 3' exonuclease activity associated with Type A polymerases which is not present in DNAP*Taq*. All constructs except the genes shown in Figs. 3E, F and G were
25 made in the pTTQ18 vector.

30 The cloning vector used for the genes in Figs. 3E and F was from the commercially available pET-3 series, described above. Though this vector series has only a *Bam*HI site for cloning downstream of the T7 promoter, the series contains variants that allow cloning into any of the three reading frames. For cloning of the PCR product described above, the variant called pET-3c was used (Fig. 14). The vector was digested with *Bam*HI, dephosphorylated with calf intestinal phosphatase, and the sticky ends were filled in using the Klenow fragment of DNAPEc1 and dNTPs. The gene for the mutant *Taq* DNAP shown in Fig. 3B (*mutTaq*,

clone 3B) was released from pTTQ18 by digestion with *EcoRI* and *Sall*, and the "sticky ends" were filled in as was done with the vector. The fragment was ligated to the vector under standard blunt-end conditions (Sambrook *et al.*, *Molecular Cloning, supra*), the construct was transformed into the BL21(DE3)pLYS strain of *E. coli*, and isolates were
5 screened to identify those that were ligated with the gene in the proper orientation relative to the promoter. This construction yields another translational fusion product, in which the first two amino acids of DNAPTaq (Met-Arg) are replaced by 13 from the vector plus two from the PCR primer (Met-Ala-Ser-Met-Thr-Gly-Gly-Gln-Gln-Met-Gly-Arg-Ile-Asn-Ser) (SEQ ID NO:24).

10 Our goal was to generate enzymes that lacked the ability to synthesize DNA, but retained the ability to cleave nucleic acids with a 5' nuclease activity. The act of primed, templated synthesis of DNA is actually a coordinated series of events, so it is possible to disable DNA synthesis by disrupting one event while not affecting the others. These steps include, but are not limited to, primer recognition and binding, dNTP binding and catalysis of
15 the inter-nucleotide phosphodiester bond. Some of the amino acids in the polymerization domain of DNAPEcI have been linked to these functions, but the precise mechanisms are as yet poorly defined.

One way of destroying the polymerizing ability of a DNA polymerase is to delete all or part of the gene segment that encodes that domain for the protein, or to otherwise render
20 the gene incapable of making a complete polymerization domain. Individual mutant enzymes may differ from each other in stability and solubility both inside and outside cells. For instance, in contrast to the 5' nuclease domain of DNAPEcI, which can be released in an active form from the polymerization domain by gentle proteolysis [Setlow and Kornberg, *J. Biol. Chem.* 247:232 (1972)], the *Thermus* nuclease domain, when treated similarly, becomes
25 less soluble and the cleavage activity is often lost.

Using the mutant gene shown in Fig. 3B as starting material, several deletion constructs were created. All cloning technologies were standard (Sambrook *et al.*, *supra*) and are summarized briefly, as follows:

Fig. 3C: The mutTaq construct was digested with *PstI*, which cuts once within the
30 polymerase coding region, as indicated, and cuts immediately downstream of the gene in the multiple cloning site of the vector. After release of the fragment between these two sites, the vector was re-ligated, creating an 894-nucleotide deletion, and bringing into frame a stop

codon 40 nucleotides downstream of the junction. The nucleotide sequence of this 5' nuclease (clone 4C) is given in SEQ ID NO:9.

Fig. 3D: The *mutTaq* construct was digested with *NheI*, which cuts once in the gene at position 2047. The resulting four-nucleotide 5' overhanging ends were filled in, as described above, and the blunt ends were re-ligated. The resulting four-nucleotide insertion changes the reading frame and causes termination of translation ten amino acids downstream of the mutation. The nucleotide sequence of this 5' nuclease (clone 3D) is given in SEQ ID NO:10.

Fig. 3E: The entire *mutTaq* gene was cut from pTTQ18 using *EcoRI* and *SaII* and cloned into pET-3c, as described above. This clone was digested with *BstXI* and *XcmI*, at unique sites that are situated as shown in Fig. 3E. The DNA was treated with the Klenow fragment of DNAPEcI and dNTPs, which resulted in the 3' overhangs of both sites being trimmed to blunt ends. These blunt ends were ligated together, resulting in an out-of-frame deletion of 1540 nucleotides. An in-frame termination codon occurs 18 triplets past the junction site. The nucleotide sequence of this 5' nuclease (clone 3E) is given in SEQ ID NO:11, with the appropriate leader sequence given in SEQ ID NO:25. It is also referred to as Cleavase® BX.

Fig. 3F: The entire *mutTaq* gene was cut from pTTQ18 using *EcoRI* and *SaII* and cloned into pET-3c, as described above. This clone was digested with *BstXI* and *BamHI*, at unique sites that are situated as shown in the diagram. The DNA was treated with the Klenow fragment of DNAPEcI and dNTPs, which resulted in the 3' overhang of the *BstXI* site being trimmed to a blunt end, while the 5' overhang of the *BamHI* site was filled in to make a blunt end. These ends were ligated together, resulting in an in-frame deletion of 903 nucleotides. The nucleotide sequence of the 5' nuclease (clone 3F) is given in SEQ ID NO:12. It is also referred to as Cleavase® BB.

Fig. 3G: This polymerase is a variant of that shown in Fig. 4E. It was cloned in the plasmid vector pET-21 (Novagen). The non-bacterial promoter from bacteriophage T7, found in this vector, initiates transcription only by T7 RNA polymerase. See Studier and Moffatt, *supra*. In a suitable strain, such as (DES)pLYS, the gene for this RNA polymerase is carried on the bacterial genome under control of the *lac* operator. This arrangement has the advantage that expression of the multiple copy gene (on the plasmid) is completely dependent on the expression of T7 RNA polymerase, which is easily suppressed because it is present in a single copy. Because the expression of these mutant genes is under this tightly controlled

promoter, potential problems of toxicity of the expressed proteins to the host cells are less of a concern.

5 The pET-21 vector also features a "His*Tag", a stretch of six consecutive histidine residues that are added on the carboxy terminus of the expressed proteins. The resulting proteins can then be purified in a single step by metal chelation chromatography, using a commercially available (Novagen) column resin with immobilized Ni⁺⁺ ions. The 2.5 ml columns are reusable, and can bind up to 20 mg of the target protein under native or denaturing (guanidine*HCl or urea) conditions.

10 *E. coli* (DES)pLYS cells are transformed with the constructs described above using standard transformation techniques, and used to inoculate a standard growth medium (e.g., Luria-Bertani broth). Production of T7 RNA polymerase is induced during log phase growth by addition of IPTG and incubated for a further 12 to 17 hours. Aliquots of culture are removed both before and after induction and the proteins are examined by SDS-PAGE. Staining with Coomassie Blue allows visualization of the foreign proteins if they account for about 3-5% of the cellular protein and do not co-migrate with any of the major protein bands. 15 Proteins that co-migrate with major host protein must be expressed as more than 10% of the total protein to be seen at this stage of analysis.

Some mutant proteins are sequestered by the cells into inclusion bodies. These are granules that form in the cytoplasm when bacteria are made to express high levels of a foreign protein, and they can be purified from a crude lysate, and analyzed by SDS-PAGE to 20 determine their protein content. If the cloned protein is found in the inclusion bodies, it must be released to assay the cleavage and polymerase activities. Different methods of solubilization may be appropriate for different proteins, and a variety of methods are known. See e.g., Builder & Ogez, U.S. Patent No. 4,511,502 (1985); Olson, U.S. Patent No. 4,518,526 (1985); Olson & Pai, U.S. Patent No. 4,511,503 (1985); Jones *et al.*, U.S. Patent 25 No. 4,512,922 (1985), all of which are hereby incorporated by reference.

The solubilized protein is then purified on the Ni⁺⁺ column as described above, following the manufacturers instructions (Novagen). The washed proteins are eluted from the column by a combination of imidazole competitor (1 M) and high salt (0.5 M NaCl), and 30 dialyzed to exchange the buffer and to allow denature proteins to refold. Typical recoveries result in approximately 20 µg of specific protein per ml of starting culture. The DNAP mutant is referred to as the Cleavase® BN nuclease and the sequence is given in SEQ ID

NO:26 (the amino acid sequence of the Cleavase® BN nuclease is obtained by translating the DNA sequence of SEQ ID NO:26).

2. Modified DNAPTII Gene

5 The DNA polymerase gene of *Thermus flavus* was isolated from the "*T. flavus*" AT-62 strain obtained from the American Type Tissue Collection (ATCC 33923). This strain has a different restriction map than does the *T. flavus* strain used to generate the sequence published by Akhmetzjanov and Vakhitov, *supra*. The published sequence is listed as SEQ ID NO:2. No sequence data has been published for the DNA polymerase gene from the AT-62 strain of
10 *T. flavus*.

Genomic DNA from *T. flavus* was amplified using the same primers used to amplify the *T. aquaticus* DNA polymerase gene (SEQ ID NOS:13-14). The approximately 2500 base pair PCR fragment was digested with *Eco*RI and *Bam*HI. The over-hanging ends were made blunt with the Klenow fragment of DNAPEcI and dNTPs. The resulting approximately 1800
15 base pair fragment containing the coding region for the N-terminus was ligated into pET-3c, as described above. This construct, clone 4B, is depicted in Fig. 4B. The wild type *T. flavus* DNA polymerase gene is depicted in Fig. 4A. The 4B clone has the same leader amino acids as do the DNAPTaq clones 4E and F which were cloned into pET-3c; it is not known precisely where translation termination occurs, but the vector has a strong transcription
20 termination signal immediately downstream of the cloning site.

B. Growth And Induction Of Transformed Cells

Bacterial cells were transformed with the constructs described above using standard transformation techniques and used to inoculate 2 mls of a standard growth medium (e.g.,
25 Luria-Bertani broth). The resulting cultures were incubated as appropriate for the particular strain used, and induced if required for a particular expression system. For all of the constructs depicted in Figs. 3 and 4, the cultures were grown to an optical density (at 600nm wavelength) of 0.5 OD.

To induce expression of the cloned genes, the cultures were brought to a final
30 concentration of 0.4 mM IPTG and the incubations were continued for 12 to 17 hours. 50 μ l aliquots of each culture were removed both before and after induction and were combined with 20 μ l of a standard gel loading buffer for sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). Subsequent staining with Coomassie Blue (Sambrook *et al.*,

supra) allows visualization of the foreign proteins if they account for about 3-5% of the cellular protein and do not co-migrate with any of the major *E. coli* protein bands. Proteins that do co-migrate with a major host protein must be expressed as more than 10% of the total protein to be seen at this stage of analysis.

5

C. Heat Lysis And Fractionation

Expressed thermostable proteins, *i.e.*, the 5' nucleases, were isolated by heating crude bacterial cell extracts to cause denaturation and precipitation of the less stable *E. coli* proteins. The precipitated *E. coli* proteins were then, along with other cell debris, removed by centrifugation. 1.7 mls of the culture were pelleted by microcentrifugation at 12,000 to 14,000 rpm for 30 to 60 seconds. After removal of the supernatant, the cells were resuspended in 400 μ l of buffer A (50 mM Tris-HCl, pH 7.9, 50 mM dextrose, 1 mM EDTA), re-centrifuged, then resuspended in 80 μ l of buffer A with 4mg/ml lysozyme. The cells were incubated at room temperature for 15 minutes, then combined with 80 μ l of buffer B (10 mM Tris-HCl, pH 7.9, 50 mM KCl, 1 mM EDTA, 1 mM PMSF, 0.5% Tween-20, 0.5% Nonidet-P40).

This mixture was incubated at 75°C for 1 hour to denature and precipitate the host proteins. This cell extract was centrifuged at 14,000 rpm for 15 minutes at 4°C, and the supernatant was transferred to a fresh tube. An aliquot of 0.5 to 1 μ l of this supernatant was used directly in each test reaction, and the protein content of the extract was determined by subjecting 7 μ l to electrophoretic analysis, as above. The native recombinant *Taq* DNA polymerase [Engle, Anal. Biochem 191:396 (1990)], and the double point mutation protein shown in Fig. 3B are both soluble and active at this point.

The foreign protein may not be detected after the heat treatments due to sequestration of the foreign protein by the cells into inclusion bodies. These are granules that form in the cytoplasm when bacteria are made to express high levels of a foreign protein, and they can be purified from a crude lysate, and analyzed SDS PAGE to determine their protein content. Many methods have been described in the literature, and one approach is described below.

30

D. Isolation And Solubilization Of Inclusion Bodies

A small culture was grown and induced as described above. A 1.7 ml aliquot was pelleted by brief centrifugation, and the bacterial cells were resuspended in 100 μ l of Lysis buffer (50 mM Tris-HCl, pH 8.0, 1 mM EDTA, 100 mM NaCl). 2.5 μ l of 20 mM PMSF

were added for a final concentration of 0.5 mM, and lysozyme was added to a concentration of 1.0 mg/ml. The cells were incubated at room temperature for 20 minutes, deoxycholic acid was added to 1mg/ml (1 μ l of 100 mg/ml solution), and the mixture was further incubated at 37°C for about 15 minutes or until viscous. DNase I was added to 10 μ g/ml and the mixture
5 was incubated at room temperature for about 30 minutes or until it was no longer viscous.

From this mixture the inclusion bodies were collected by centrifugation at 14,000 rpm for 15 minutes at 4°C, and the supernatant was discarded. The pellet was resuspended in 100 μ l of lysis buffer with 10mM EDTA (pH 8.0) and 0.5% Triton X-100. After 5 minutes at room temperature, the inclusion bodies were pelleted as before, and the supernatant was saved
10 for later analysis. The inclusion bodies were resuspended in 50 μ l of distilled water, and 5 μ l was combined with SDS gel loading buffer (which dissolves the inclusion bodies) and analyzed electrophoretically, along with an aliquot of the supernatant.

If the cloned protein is found in the inclusion bodies, it may be released to assay the cleavage and polymerase activities and the method of solubilization must be compatible with
15 the particular activity. Different methods of solubilization may be appropriate for different proteins, and a variety of methods are discussed in *Molecular Cloning* (Sambrook *et al.*, *supra*). The following is an adaptation we have used for several of our isolates.

20 μ l of the inclusion body-water suspension were pelleted by centrifugation at 14,000 rpm for 4 minutes at room temperature, and the supernatant was discarded. To further wash the inclusion bodies, the pellet was resuspended in 20 μ l of lysis buffer with 2M urea, and incubated at room temperature for one hour. The washed inclusion bodies were then resuspended in 2 μ l of lysis buffer with 8M urea; the solution clarified visibly as the inclusion bodies dissolved. Undissolved debris was removed by centrifugation at 14,000 rpm for 4 minutes at room temperature, and the extract supernatant was transferred to a fresh tube.

25 To reduce the urea concentration, the extract was diluted into KH_2PO_4 . A fresh tube was prepared containing 180 μ l of 50 mM KH_2PO_4 , pH 9.5, 1 mM EDTA and 50 mM NaCl. A 2 μ l aliquot of the extract was added and vortexed briefly to mix. This step was repeated until all of the extract had been added for a total of 10 additions. The mixture was allowed to sit at room temperature for 15 minutes, during which time some precipitate often forms.
30 Precipitates were removed by centrifugation at 14,000 rpm, for 15 minutes at room temperature, and the supernatant was transferred to a fresh tube. To the 200 μ l of protein in the KH_2PO_4 solution, 140-200 μ l of saturated $(\text{NH}_4)_2\text{SO}_4$ were added, so that the resulting mixture was about 41% to 50% saturated $(\text{NH}_4)_2\text{SO}_4$. The mixture was chilled on ice for 30

minutes to allow the protein to precipitate, and the protein was then collected by centrifugation at 14,000 rpm, for 4 minutes at room temperature. The supernatant was discarded, and the pellet was dissolved in 20 μ l Buffer C (20 mM HEPES, pH 7.9, 1 mM EDTA, 0.5% PMSF, 25 mM KCl and 0.5 % each of Tween-20 and Nonidet P 40). The protein solution was centrifuged again for 4 minutes to pellet insoluble materials, and the supernatant was removed to a fresh tube. The protein contents of extracts prepared in this manner were visualized by resolving 1-4 μ l by SDS-PAGE: 0.5 to 1 μ l of extract was tested in the cleavage and polymerization assays as described.

E. Protein Analysis For Presence Of Nuclease And Synthetic Activity

The 5' nucleases described above and shown in Figs. 3 and 4 were analyzed by the following methods.

1. Structure Specific Nuclease Assay

A candidate modified polymerase is tested for 5' nuclease activity by examining its ability to catalyze structure-specific cleavages. By the term "cleavage structure" as used herein, is meant a nucleic acid structure which is a substrate for cleavage by the 5' nuclease activity of a DNAP.

The polymerase is exposed to test complexes that have the structures shown in Fig. 15. Testing for 5' nuclease activity involves three reactions: 1) a primer-directed cleavage (Fig. 15B) is performed because it is relatively insensitive to variations in the salt concentration of the reaction and can, therefore, be performed in whatever solute conditions the modified enzyme requires for activity; this is generally the same conditions preferred by unmodified polymerases; 2) a similar primer-directed cleavage is performed in a buffer which permits primer-independent cleavage, *i.e.*, a low salt buffer, to demonstrate that the enzyme is viable under these conditions; and 3) a primer-independent cleavage (Fig. 15A) is performed in the same low salt buffer.

The bifurcated duplex is formed between a substrate strand and a template strand as shown in Fig. 15. By the term "substrate strand" as used herein, is meant that strand of nucleic acid in which the cleavage mediated by the 5' nuclease activity occurs. The substrate strand is always depicted as the top strand in the bifurcated complex which serves as a substrate for 5' nuclease cleavage (Fig. 15). By the term "template strand" as used herein, is

meant the strand of nucleic acid which is at least partially complementary to the substrate strand and which anneals to the substrate strand to form the cleavage structure. The template strand is always depicted as the bottom strand of the bifurcated cleavage structure (Fig. 15). If a primer (a short oligonucleotide of 19 to 30 nucleotides in length) is added to the complex, as when primer-dependent cleavage is to be tested, it is designed to anneal to the 3' arm of the template strand (Fig. 15B). Such a primer would be extended along the template strand if the polymerase used in the reaction has synthetic activity.

The cleavage structure may be made as a single hairpin molecule, with the 3' end of the target and the 5' end of the pilot joined as a loop as shown in Fig. 15E. A primer oligonucleotide complementary to the 3' arm is also required for these tests so that the enzyme's sensitivity to the presence of a primer may be tested.

Nucleic acids to be used to form test cleavage structures can be chemically synthesized, or can be generated by standard recombinant DNA techniques. By the latter method, the hairpin portion of the molecule can be created by inserting into a cloning vector duplicate copies of a short DNA segment, adjacent to each other but in opposing orientation. The double-stranded fragment encompassing this inverted repeat, and including enough flanking sequence to give short (about 20 nucleotides) unpaired 5' and 3' arms, can then be released from the vector by restriction enzyme digestion, or by PCR performed with an enzyme lacking a 5' exonuclease (e.g., the Stoffel fragment of Amplitaq™ DNA polymerase, Vent™ DNA polymerase).

The test DNA can be labeled on either end, or internally, with either a radioisotope, or with a non-isotopic tag. Whether the hairpin DNA is a synthetic single strand or a cloned double strand, the DNA is heated prior to use to melt all duplexes. When cooled on ice, the structure depicted in Fig. 16E is formed, and is stable for sufficient time to perform these assays.

To test for primer-directed cleavage (Reaction 1), a detectable quantity of the test molecule (typically 1-100 fmol of ³²P-labeled hairpin molecule) and a 10 to 100-fold molar excess of primer are placed in a buffer known to be compatible with the test enzyme. For Reaction 2, where primer-directed cleavage is performed under condition which allow primer-independent cleavage, the same quantities of molecules are placed in a solution that is the same as the buffer used in Reaction 1 regarding pH, enzyme stabilizers (e.g., bovine serum albumin, nonionic detergents, gelatin) and reducing agents (e.g., dithiothreitol, 2-mercaptoethanol) but that replaces any monovalent cation salt with 20 mM KCl; 20 mM

KCl is the demonstrated optimum for primer-independent cleavage. Buffers for enzymes, such as DNAPEc1, that usually operate in the absence of salt are not supplemented to achieve this concentration. To test for primer-independent cleavage (Reaction 3) the same quantity of the test molecule, but no primer, are combined under the same buffer conditions used for Reaction 2.

All three test reactions are then exposed to enough of the enzyme that the molar ratio of enzyme to test complex is approximately 1:1. The reactions are incubated at a range of temperatures up to, but not exceeding, the temperature allowed by either the enzyme stability or the complex stability, whichever is lower, up to 80°C for enzymes from thermophiles, for a time sufficient to allow cleavage (10 to 60 minutes). The products of Reactions 1, 2 and 3 are resolved by denaturing polyacrylamide gel electrophoresis, and visualized by autoradiography or by a comparable method appropriate to the labeling system used. Additional labeling systems include chemiluminescence detection, silver or other stains, blotting and probing and the like. The presence of cleavage products is indicated by the presence of molecules which migrate at a lower molecular weight than does the uncleaved test structure. These cleavage products indicate that the candidate polymerase has structure-specific 5' nuclease activity.

To determine whether a modified DNA polymerase has substantially the same 5' nuclease activity as that of the native DNA polymerase, the results of the above-described tests are compared with the results obtained from these tests performed with the native DNA polymerase. By "substantially the same 5' nuclease activity" we mean that the modified polymerase and the native polymerase will both cleave test molecules in the same manner. It is not necessary that the modified polymerase cleave at the same rate as the native DNA polymerase.

Some enzymes or enzyme preparations may have other associated or contaminating activities that may be functional under the cleavage conditions described above and that may interfere with 5' nuclease detection. Reaction conditions can be modified in consideration of these other activities, to avoid destruction of the substrate, or other masking of the 5' nuclease cleavage and its products. For example, the DNA polymerase I of *E. coli* (Pol I), in addition to its polymerase and 5' nuclease activities, has a 3' exonuclease that can degrade DNA in a 3' to 5' direction. Consequently, when the molecule in Fig. 15E is exposed to this polymerase under the conditions described above, the 3' exonuclease quickly removes the unpaired 3' arm, destroying the bifurcated structure required of a substrate for the 5'

exonuclease cleavage and no cleavage is detected. The true ability of Pol I to cleave the structure can be revealed if the 3' exonuclease is inhibited by a change of conditions (*e.g.*, pH), mutation, or by addition of a competitor for the activity. Addition of 500 pmoles of a single-stranded competitor oligonucleotide, unrelated to the Fig. 15E structure, to the cleavage reaction with Pol I effectively inhibits the digestion of the 3' arm of the Fig. 15E structure without interfering with the 5' exonuclease release of the 5' arm. The concentration of the competitor is not critical, but should be high enough to occupy the 3' exonuclease for the duration of the reaction.

Similar destruction of the test molecule may be caused by contaminants in the candidate polymerase preparation. Several sets of the structure specific nuclease reactions may be performed to determine the purity of the candidate nuclease and to find the window between under and over exposure of the test molecule to the polymerase preparation being investigated.

The above described modified polymerases were tested for 5' nuclease activity as follows: Reaction 1 was performed in a buffer of 10 mM Tris-Cl, pH 8.5 at 20°C, 1.5 mM MgCl₂ and 50 mM KCl and in Reaction 2 the KCl concentration was reduced to 20 mM. In Reactions 1 and 2, 10 fmoles of the test substrate molecule shown in Fig. 15E were combined with 1 pmole of the indicated primer and 0.5 to 1.0 µl of extract containing the modified polymerase (prepared as described above). This mixture was then incubated for 10 minutes at 55°C. For all of the mutant polymerases tested these conditions were sufficient to give complete cleavage. When the molecule shown in Fig. 15E was labeled at the 5' end, the released 5' fragment, 25 nucleotides long, was conveniently resolved on a 20% polyacrylamide gel (19:1 cross-linked) with 7 M urea in a buffer containing 45 mM Tris-borate pH 8.3, 1.4 mM EDTA. Clones 3C-F and 4B exhibited structure-specific cleavage comparable to that of the unmodified DNA polymerase. Additionally, clones 3E, 3F and 3G have the added ability to cleave DNA in the absence of a 3' arm as discussed above.

Representative cleavage reactions are shown in Fig. 16.

For the reactions shown in Fig. 16, the mutant polymerase clones 3E (*Taq* mutant) and 4B (*Tfl* mutant) were examined for their ability to cleave the hairpin substrate molecule shown in Fig. 15E. The substrate molecule was labeled at the 5' terminus with ³²P. Ten fmoles of heat-denatured, end-labeled substrate DNA and 0.5 units of DNAP_{Taq} (lane 1) or 0.5 µl of 3E or 4B extract (Fig. 16, lanes 2-7, extract was prepared as described above) were mixed together in a buffer containing 10 mM Tris-Cl, pH 8.5, 50 mM KCl and 1.5 mM

MgCl₂. The final reaction volume was 10 µl. Reactions shown in lanes 4 and 7 contain in addition 50 µM of each dNTP. Reactions shown in lanes 3, 4, 6 and 7 contain 0.2 µM of the primer oligonucleotide (complementary to the 3' arm of the substrate and shown in Fig. 15E). Reactions were incubated at 55° C for 4 minutes. Reactions were stopped by the addition of 8 µl of 95% formamide containing 20 mM EDTA and 0.05% marker dyes per 10 µl reaction volume. Samples were then applied to 12% denaturing acrylamide gels. Following electrophoresis, the gels were autoradiographed. Fig. 16 shows that clones 3E and 4B exhibit cleavage activity similar to that of the native DNAP_{Taq}. Note that some cleavage occurs in these reactions in the absence of the primer. When long hairpin structure, such as the one used here (Fig. 15E), are used in cleavage reactions performed in buffers containing 50 mM KCl a low level of primer-independent cleavage is seen. Higher concentrations of KCl suppress, but do not eliminate, this primer-independent cleavage under these conditions.

2. Assay For Synthetic Activity

The ability of the modified enzyme or proteolytic fragments is assayed by adding the modified enzyme to an assay system in which a primer is annealed to a template and DNA synthesis is catalyzed by the added enzyme. Many standard laboratory techniques employ such an assay. For example, nick translation and enzymatic sequencing involve extension of a primer along a DNA template by a polymerase molecule.

In a preferred assay for determining the synthetic activity of a modified enzyme an oligonucleotide primer is annealed to a single-stranded DNA template, *e.g.*, bacteriophage M13 DNA, and the primer/template duplex is incubated in the presence of the modified polymerase in question, deoxynucleoside triphosphates (dNTPs) and the buffer and salts known to be appropriate for the unmodified or native enzyme. Detection of either primer extension (by denaturing gel electrophoresis) or dNTP incorporation (by acid precipitation or chromatography) is indicative of an active polymerase. A label, either isotopic or non-isotopic, is preferably included on either the primer or as a dNTP to facilitate detection of polymerization products. Synthetic activity is quantified as the amount of free nucleotide incorporated into the growing DNA chain and is expressed as amount incorporated per unit of time under specific reaction conditions.

Representative results of an assay for synthetic activity is shown in Fig. 17. The synthetic activity of the mutant DNAP_{Taq} clones 3B-F was tested as follows: A master mixture of the following buffer was made: 1.2X PCR buffer (1X PCR buffer contains 50

mM KCl, 1.5 mM MgCl₂, 10 mM Tris-Cl, pH 8.5 and 0.05% each Tween 20 and Nonidet P40), 50 μ M each of dGTP, dATP and dTTP, 5 μ M dCTP and 0.125 μ M α -³²P-dCTP at 600 Ci/mmol. Before adjusting this mixture to its final volume, it was divided into two equal aliquots. One received distilled water up to a volume of 50 μ l to give the concentrations
5 above. The other received 5 μ g of single-stranded M13mp18 DNA (approximately 2.5 pmol or 0.05 μ M final concentration) and 250 pmol of M13 sequencing primer (5 μ M final concentration) and distilled water to a final volume of 50 μ l. Each cocktail was warmed to 75°C for 5 minutes and then cooled to room temperature. This allowed the primers to anneal to the DNA in the DNA-containing mixtures.

10 For each assay, 4 μ l of the cocktail with the DNA was combined with 1 μ l of the mutant polymerase, prepared as described, or 1 unit of DNAP Taq (Perkin Elmer) in 1 μ l of dH₂O. A "no DNA" control was done in the presence of the DNAP Taq (Fig. 17, lane 1), and a "no enzyme" control was done using water in place of the enzyme (lane 2). Each reaction was mixed, then incubated at room temperature (approx. 22°C) for 5 minutes, then at 55°C
15 for 2 minutes, then at 72°C for 2 minutes. This step incubation was done to detect polymerization in any mutants that might have optimal temperatures lower than 72°C. After the final incubation, the tubes were spun briefly to collect any condensation and were placed on ice. One μ l of each reaction was spotted at an origin 1.5 cm from the bottom edge of a polyethyleneimine (PEI) cellulose thin layer chromatography plate and allowed to dry. The
20 chromatography plate was run in 0.75 M NaH₂PO₄, pH 3.5, until the buffer front had run approximately 9 cm from the origin. The plate was dried, wrapped in plastic wrap, marked with luminescent ink, and exposed to X-ray film. Incorporation was detected as counts that stuck where originally spotted, while the unincorporated nucleotides were carried by the salt solution from the origin.

25 Comparison of the locations of the counts with the two control lanes confirmed the lack of polymerization activity in the mutant preparations. Among the modified DNAP Taq clones, only clone 3B retains any residual synthetic activity as shown in Fig. 17.

EXAMPLE 3

5' Nucleases Derived From Thermostable DNA
Polymerases Can Cleave Short Hairpin Structures With Specificity

5 The ability of the 5' nucleases to cleave hairpin structures to generate a cleaved hairpin structure suitable as a detection molecule was examined. The structure and sequence of the hairpin test molecule is shown in Fig. 18A (SEQ ID NO:15). The oligonucleotide (labeled "primer" in Fig. 18A, SEQ ID NO:22) is shown annealed to its complementary sequence on the 3' arm of the hairpin test molecule. The hairpin test molecule was single-end
10 labeled with ^{32}P using a labeled T7 promoter primer in a polymerase chain reaction. The label is present on the 5' arm of the hairpin test molecule and is represented by the star in Fig. 18A.

The cleavage reaction was performed by adding 10 fmoles of heat-denatured, end-labeled hairpin test molecule, 0.2 μM of the primer oligonucleotide (complementary to the 3'
15 arm of the hairpin), 50 μM of each dNTP and 0.5 units of DNAP Taq (Perkin Elmer) or 0.5 μl of extract containing a 5' nuclease (prepared as described above) in a total volume of 10 μl in a buffer containing 10 mM Tris-Cl, pH 8.5, 50 mM KCl and 1.5 mM MgCl_2 . Reactions shown in lanes 3, 5 and 7 were run in the absence of dNTPs.

Reactions were incubated at 55° C for 4 minutes. Reactions were stopped at 55° C by
20 the addition of 8 μl of 95% formamide with 20 mM EDTA and 0.05% marker dyes per 10 μl reaction volume. Samples were not heated before loading onto denaturing polyacrylamide gels (10% polyacrylamide, 19:1 crosslinking, 7 M urea, 89 mM Tris-borate, pH 8.3, 2.8 mM EDTA). The samples were not heated to allow for the resolution of single-stranded and re-duplexed uncleaved hairpin molecules.

25 Fig. 18B shows that altered polymerases lacking any detectable synthetic activity cleave a hairpin structure when an oligonucleotide is annealed to the single-stranded 3' arm of the hairpin to yield a single species of cleaved product (Fig. 18B, lanes 3 and 4). 5' nucleases, such as clone 3D, shown in lanes 3 and 4, produce a single cleaved product even in the presence of dNTPs. 5' nucleases which retain a residual amount of synthetic activity (less
30 than 1% of wild type activity) produce multiple cleavage products as the polymerase can extend the oligonucleotide annealed to the 3' arm of the hairpin thereby moving the site of cleavage (clone 3B, lanes 5 and 6). Native DNAP Taq produces even more species of cleavage products than do mutant polymerases retaining residual synthetic activity and additionally

converts the hairpin structure to a double-stranded form in the presence of dNTPs due to the high level of synthetic activity in the native polymerase (Fig. 18B, lane 8).

EXAMPLE 4

Cleavage Of Linear Nucleic Acid Substrates

From the above, it should be clear that native (*i.e.*, "wild type") thermostable DNA polymerases are capable of cleaving hairpin structures in a specific manner and that this discovery can be applied with success to a detection assay. In this example, the mutant DNAPs of the present invention are tested against three different cleavage structures shown in Fig. 20A. Structure 1 in Fig. 20A is simply single stranded 206-mer (the preparation and sequence information for which was discussed in Example 1C). Structures 2 and 3 are duplexes: structure 2 is the same hairpin structure as shown in Fig. 11A (bottom), while structure 3 has the hairpin portion of structure 2 removed.

The cleavage reactions comprised 0.01 pmoles of the resulting substrate DNA, and 1 pmole of pilot oligonucleotide in a total volume of 10 μ l of 10 mM Tris-Cl, pH 8.3, 100 mM KCl, 1 mM $MgCl_2$. Reactions were incubated for 30 minutes at 55°C. and stopped by the addition of 8 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 10% polyacrylamide gel (19:1 cross link), with 7M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

The results were visualized by autoradiography and are shown in Fig. 20B with the enzymes indicated as follows: I is native *Taq* DNAP; II is native *Tfl* DNAP; III is Cleavase® BX shown in Fig. 3E; IV is Cleavase® BB shown in Fig. 3F; V is the mutant shown in Fig. 4B; and VI is Cleavase® BN shown in Fig. 3G.

Structure 2 was used to "normalize" the comparison. For example, it was found that it took 50 ng of *Taq* DNAP and 300 ng of Cleavase® BN to give similar amounts of cleavage of Structure 2 in thirty (30) minutes. Under these conditions native *Taq* DNAP is unable to cleave Structure 3 to any significant degree. Native *Tfl* DNAP cleaves Structure 3 in a manner that creates multiple products.

By contrast, all of the mutants tested cleave the linear duplex of Structure 3. This finding indicates that this characteristic of the mutant DNA polymerases is consistent of thermostable polymerases across thermophilic species.

EXAMPLE 5

5' Exonucleolytic Cleavage ("Nibbling") By Thermostable DNAPs

It has been found that thermostable DNAPs, including those of the present invention, have a true 5' exonuclease capable of nibbling the 5' end of a linear duplex nucleic acid structures. In this example, the 206 base pair DNA duplex substrate is again employed (see Example 1C). In this case, it was produced by the use of one ³²P-labeled primer and one unlabeled primer in a polymerase chain reaction. The cleavage reactions comprised 0.01 pmoles of heat-denatured, end-labeled substrate DNA (with the unlabeled strand also present), 5 pmoles of pilot oligonucleotide (see pilot oligos in Fig. 11A) and 0.5 units of DNAP[®]Taq or 0.5 μ of Cleavase[®] BB in the *E. coli* extract (see above), in a total volume of 10 μ l of 10 mM Tris•Cl, pH 8.5, 50 mM KCl, 1.5 mM MgCl₂.

Reactions were initiated at 65°C by the addition of pre-warmed enzyme, then shifted to the final incubation temperature for 30 minutes. The results are shown in Fig. 21A. Samples in lanes 1-4 are the results with native *Taq* DNAP, while lanes 5-8 shown the results with Cleavase[®] BB. The reactions for lanes 1, 2, 5, and 6 were performed at 65°C and reactions for lanes 3, 4, 7, and 8 were performed at 50°C and all were stopped at temperature by the addition of 8 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 10% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris•Borate, pH 8.3, 1.4 mM EDTA. The expected product in reactions 1, 2, 5, and 6 is 85 nucleotides long; in reactions 3 and 7, the expected product is 27 nucleotides long. Reactions 4 and 8 were performed without pilot, and should remain at 206 nucleotides. The faint band seen at 24 nucleotides is residual end-labeled primer from the PCR.

The surprising result is that Cleavase[®] BB under these conditions causes all of the label to appear in a very small species, suggesting the possibility that the enzyme completely hydrolyzed the substrate. To determine the composition of the fastest-migrating band seen in lanes 5-8 (reactions performed with the deletion mutant), samples of the 206 base pair duplex were treated with either T7 gene 6 exonuclease (USB) or with calf intestine alkaline phosphatase (Promega), according to manufacturers' instructions, to produce either labeled mononucleotide (lane a of Fig. 21B) or free ³²P-labeled inorganic phosphate (lane b of Fig. 21B), respectively. These products, along with the products seen in lane 7 of panel A were resolved by brief electrophoresis through a 20% acrylamide gel (19:1 cross-link), with 7

M urea. in a buffer of 45 mM Tris•Borate, pH 8.3, 1.4 mM EDTA. Cleavase® BB is thus capable of converting the substrate to mononucleotides.

EXAMPLE 6

Nibbling Is Duplex Dependent

5 The nibbling by Cleavase® BB is duplex dependent. In this example, internally labeled, single strands of the 206-mer were produced by 15 cycles of primer extension incorporating α -³²P labeled dCTP combined with all four unlabeled dNTPs, using an
10 unlabeled 206-bp fragment as a template. Single and double stranded products were resolved by electrophoresis through a non-denaturing 6% polyacrylamide gel (29:1 cross-link) in a buffer of 45 mM Tris•Borate, pH 8.3, 1.4 mM EDTA, visualized by autoradiography, excised from the gel, eluted by passive diffusion, and concentrated by ethanol precipitation.

The cleavage reactions comprised 0.04 pmoles of substrate DNA, and 2 μ l of
15 Cleavase® BB (in an *E. coli* extract as described above) in a total volume of 40 μ l of 10 mM Tris•Cl, pH 8.5, 50 mM KCl, 1.5 mM MgCl₂. Reactions were initiated by the addition of pre-warmed enzyme: 10 μ l aliquots were removed at 5, 10, 20, and 30 minutes, and transferred to prepared tubes containing 8 μ l of 95% formamide with 30 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before
20 electrophoresis through a 10% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris•Borate, pH 8.3, 1.4 mM EDTA. Results were visualized by autoradiography as shown in Fig. 22. Clearly, the cleavage by Cleavase® BB depends on a duplex structure: no cleavage of the single strand structure is detected whereas cleavage of the 206-mer duplex is complete.

25

EXAMPLE 7

Nibbling Can Be Target Directed

The nibbling activity of the DNAPs of the present invention can be employed with
30 success in a detection assay. One embodiment of such an assay is shown in Fig. 23. In this assay, a labelled oligo is employed that is specific for a target sequence. The oligo is in excess of the target so that hybridization is rapid. In this embodiment, the oligo contains two fluorescein labels whose proximity on the oligo causes their emission to be quenched. When

the DNAP is permitted to nibble the oligo the labels separate and are detectable. The shortened duplex is destabilized and disassociates. Importantly, the target is now free to react with an intact labelled oligo. The reaction can continue until the desired level of detection is achieved. An analogous, although different, type of cycling assay has been described
5 employing lambda exonuclease. See C.G. Copley and C. Boot. *BioTechniques* 13:888 (1992).

The success of such an assay depends on specificity. In other words, the oligo must hybridize to the specific target. It is also preferred that the assay be sensitive: the oligo ideally should be able to detect small amounts of target. Fig. 24A shows a 5'-end ³²P-labelled primer bound to a plasmid target sequence. In this case, the plasmid was pUC19
10 (commercially available) which was heat denatured by boiling two (2) minutes and then quick chilling. The primer is a 21-mer (SEQ ID NO:28). The enzyme employed was Cleavase® BX (a dilution equivalent to 5 x 10⁻³ µl extract) in 100 mM KCl, 10 mM Tris-Cl, pH 8.3, 2 mM MnCl₂. The reaction was performed at 55°C for sixteen (16) hours with or without genomic background DNA (from chicken blood). The reaction was stopped by the addition
15 of 8 µl of 95% formamide with 20 mM EDTA and marker dyes.

The products of the reaction were resolved by PAGE (10% polyacrylamide, 19:1 cross link, 1X TBE) as seen in Fig. 24B. Lane "M" contains the labelled 21-mer. Lanes 1-3 contain no specific target, although Lanes 2 and 3 contain 100 ng and 200 ng of genomic DNA, respectively. Lanes 4, 5 and 6 all contain specific target with either 0 ng, 100 ng or
20 200 ng of genomic DNA, respectively. It is clear that conversion to mononucleotides occurs in Lanes 4, 5 and 6 regardless of the presence or amount of background DNA. Thus, the nibbling can be target directed and specific.

EXAMPLE 8

25 Cleavase Purification

As noted above, expressed thermostable proteins, *i.e.*, the 5' nucleases, were isolated by crude bacterial cell extracts. The precipitated *E. coli* proteins were then, along with other cell debris, removed by centrifugation. In this example, cells expressing the BN clone were
30 cultured and collected (500 grams). For each gram (wet weight) of *E. coli*, 3 ml of lysis buffer (50 mM Tris-HCl, pH 8.0, 1 mM EDTA, 100µM NaCl) was added. The cells were lysed with 200 µg/ml lysozyme at room temperature for 20 minutes. Thereafter deoxycholic

acid was added to make a 0.2% final concentration and the mixture was incubated 15 minutes at room temperature.

The lysate was sonicated for approximately 6-8 minutes at 0°C. The precipitate was removed by centrifugation (39,000g for 20 minutes). Polyethyleneimine was added (0.5%) to the supernatant and the mixture was incubated on ice for 15 minutes.

The mixture was centrifuged (5,000g for 15 minutes) and the supernatant was retained. This was heated for 30 minutes at 60°C and then centrifuged again (5,000g for 15 minutes) and the supernatant was again retained.

The supernatant was precipitated with 35% ammonium sulfate at 4°C for 15 minutes. The mixture was then centrifuged (5,000g for 15 minutes) and the supernatant was removed. The precipitate was then dissolved in 0.25M KCl, 20 Tris pH 7.6, 0.2% Tween and 0.1 EDTA) and then dialyzed against Binding Buffer (8X Binding Buffer comprises: 40mM imidazole, 4M NaCl, 160mM Tris-HCl, pH 7.9).

The solubilized protein is then purified on the Ni²⁺ column (Novagen). The Binding Buffer is allowed to drain to the top of the column bed and load the column with the prepared extract. A flow rate of about 10 column volumes per hour is optimal for efficient purification. If the flow rate is too fast, more impurities will contaminate the eluted fraction.

The column is washed with 25 ml (10 volumes) of 1X Binding Buffer and then washed with 15 ml (6 volumes) of 1X Wash Buffer (8X Wash Buffer comprises: 480mM imidazole, 4M NaCl, 160mM Tris-HCl, pH 7.9). The bound protein was eluted with 15 ml (6 volumes) of 1X Elute Buffer (4X Elute Buffer comprises: 4mM imidazole, 2M NaCl, 80mM Tris-HCl, pH 7.9). Protein is then reprecipitated with 35% Ammonium Sulfate as above. The precipitate was then dissolved and dialyzed against: 20mM Tris, 100mM KCl, 1mM EDTA). The solution was brought up to 0.1% each of Tween 20 and NP-40 and stored at 4°C.

EXAMPLE 9

The Use Of Various Divalent Cations In The Cleavage Reaction Influences The Nature Of The Resulting Cleavage Products

In comparing the 5' nucleases generated by the modification and/or deletion of the C-terminal polymerization domain of *Thermus aquaticus* DNA polymerase (DNAPTaq), as diagrammed in Fig. 3B-G, significant differences in the strength of the interactions of these

proteins with the 3' end of primers located upstream of the cleavage site (as depicted in Fig. 5) were noted. In describing the cleavage of these structures by Pol I-type DNA polymerases [Example 1 and Lyamichev *et al.* (1993) Science 260:778], it was observed that in the absence of a primer, the location of the junction between the double-stranded region and the single-stranded 5' and 3' arms determined the site of cleavage, but in the presence of a primer, the location of the 3' end of the primer became the determining factor for the site of cleavage. It was postulated that this affinity for the 3' end was in accord with the synthesizing function of the DNA polymerase.

Structure 2, shown in Fig. 20A, was used to test the effects of a 3' end proximal to the cleavage site in cleavage reactions comprising several different solutions [e.g., solutions containing different salts (KCl or NaCl), different divalent cations (Mn^{2+} or Mg^{2+}), etc.] as well as the use of different temperatures for the cleavage reaction. When the reaction conditions were such that the binding of the enzyme (e.g., a DNAP comprising a 5' nuclease, a modified DNAP or a 5' nuclease) to the 3' end (of the pilot oligonucleotide) near the cleavage site was strong, the structure shown is cleaved at the site indicated in Fig. 20A. This cleavage releases the unpaired 5' arm and leaves a nick between the remaining portion of the target nucleic acid and the folded 3' end of the pilot oligonucleotide. In contrast, when the reaction conditions are such that the binding of the DNAP (comprising a 5' nuclease) to the 3' end was weak, the initial cleavage was as described above, but after the release of the 5' arm, the remaining duplex is digested by the exonuclease function of the DNAP.

One way of weakening the binding of the DNAP to the 3' end is to remove all or part of the domain to which at least some of this function has been attributed. Some of 5' nucleases created by deletion of the polymerization domain of DNAPtaq have enhanced true exonuclease function, as demonstrated in Example 5.

The affinity of these types of enzymes (*i.e.*, 5' nucleases associated with or derived from DNAPs) for recessed 3' ends may also be affected by the identity of the divalent cation present in the cleavage reaction. It was demonstrated by Longley *et al.* [Nucl. Acids Res. 18:7317 (1990)] that the use of $MnCl_2$ in a reaction with DNAPtaq enabled the polymerase to remove nucleotides from the 5' end of a primer annealed to a template, albeit inefficiently. Similarly, by examination of the cleavage products generated using Structure 2 from Fig. 20A, as described above, in a reaction containing either DNAPtaq or the Cleavase® BB nuclease, it was observed that the substitution of $MnCl_2$ for $MgCl_2$ in the cleavage reaction resulted in the exonucleolytic "nibbling" of the duplex downstream of the initial cleavage site.

While not limiting the invention to any particular mechanism, it is thought that the substitution of MnCl_2 for MgCl_2 in the cleavage reaction lessens the affinity of these enzymes for recessed 3' ends.

5 In all cases, the use of MnCl_2 enhances the 5' nuclease function, and in the case of the Cleavase® BB nuclease, a 50- to 100-fold stimulation of the 5' nuclease function is seen. Thus, while the exonuclease activity of these enzymes was demonstrated above in the presence of MgCl_2 , the assays described below show a comparable amount of exonuclease activity using 50 to 100-fold less enzyme when MnCl_2 is used in place of MgCl_2 . When these reduced amounts of enzyme are used in a reaction mixture containing MgCl_2 , the nibbling or
10 exonuclease activity is much less apparent than that seen in Examples 5-7.

Similar effects are observed in the performance of the nucleic acid detection assay described in Examples 10-39 below when reactions performed in the presence of either MgCl_2 or MnCl_2 are compared. In the presence of either divalent cation, the presence of the invader oligonucleotide (described below) forces the site of cleavage into the probe duplex, but in the
15 presence of MnCl_2 the probe duplex can be further nibbled producing a ladder of products that are visible when a 3' end label is present on the probe oligonucleotide. When the invader oligonucleotide is omitted from a reaction containing Mn^{2+} , the probe is nibbled from the 5' end. Mg^{2+} -based reactions display minimal nibbling of the probe oligonucleotide. In any of these cases, the digestion of the probe is dependent upon the presence of the target
20 nucleic acid. In the examples below, the ladder produced by the enhanced nibbling activity observed in the presence of Mn^{2+} is used as a positive indicator that the probe oligonucleotide has hybridized to the target sequence.

EXAMPLE 10

25 Invasive 5' Endonucleolytic Cleavage By Thermostable 5' Nucleases In The Absence of Polymerization

As described in the examples above, 5' nucleases cleave near the junction between
30 single-stranded and base-paired regions in a bifurcated duplex, usually about one base pair into the base-paired region. In this example, it is shown that thermostable 5' nucleases, including those of the present invention (e.g., Cleavase® BN nuclease, Cleavase® A/G nuclease), have the ability to cleave a greater distance into the base paired region when

provided with an upstream oligonucleotide bearing a 3' region that is homologous to a 5' region of the subject duplex, as shown in Fig. 26.

Fig. 26 shows a synthetic oligonucleotide which was designed to fold upon itself which consists of the following sequence: 5'-GTTCTCTGCTCTCTGGTCGCTG
 5 TCTCGCTTGTGAAACAAGCGAGACAGCGTGGTCTCTCG-3' (SEQ ID NO:29). This oligonucleotide is referred to as the "S-60 Hairpin." The 15 basepair hairpin formed by this oligonucleotide is further stabilized by a "tri-loop" sequence in the loop end (*i.e.*, three nucleotides form the loop portion of the hairpin) [Hiraro, I. *et al.* (1994) Nucleic Acids Res. 22(4):576]. Fig. 26 also show the sequence of the P-15 oligonucleotide and the location of
 10 the region of complementarity shared by the P-15 and S-60 hairpin oligonucleotides. The sequence of the P-15 oligonucleotide is 5'-CGAGAGACCGCTG-3' (SEQ ID NO:30). As discussed in detail below, the solid black arrowheads shown in Fig. 26 indicate the sites of cleavage of the S-60 hairpin in the absence of the P-15 oligonucleotide and the hollow arrow heads indicate the sites of cleavage in the presence of the P-15 oligonucleotide. The size of
 15 the arrow head indicates the relative utilization of a particular site.

The S-60 hairpin molecule was labeled on its 5' end with biotin for subsequent detection. The S-60 hairpin was incubated in the presence of a thermostable 5' nuclease in the presence or the absence of the P-15 oligonucleotide. The presence of the full duplex which can be formed by the S-60 hairpin is demonstrated by cleavage with the Cleavase® BN
 20 5' nuclease, in a primer-independent fashion (*i.e.*, in the absence of the P-15 oligonucleotide). The release of 18 and 19-nucleotide fragments from the 5' end of the S-60 hairpin molecule showed that the cleavage occurred near the junction between the single and double stranded regions when nothing is hybridized to the 3' arm of the S-60 hairpin (Fig. 27, lane 2).

The reactions shown in Fig. 27 were conducted as follows. Twenty fmole of the 5' biotin-labeled hairpin DNA (SEQ ID NO:29) was combined with 0.1 ng of Cleavase® BN
 25 enzyme and 1 µl of 100 mM MOPS (pH 7.5) containing 0.5% each of Tween-20 and NP-40 in a total volume of 9 µl. In the reaction shown in lane 1, the enzyme was omitted and the volume was made up by addition of distilled water (this served as the uncut or no enzyme control). The reaction shown in lane 3 of Fig. 27 also included 0.5 pmole of the P15
 30 oligonucleotide (SEQ ID NO:30), which can hybridize to the unpaired 3' arm of the S-60 hairpin (SEQ ID NO:29), as diagrammed in Fig. 26.

The reactions were overlaid with a drop of mineral oil, heated to 95°C for 15 seconds, then cooled to 37°C, and the reaction was started by the addition of 1 µl of 10 mM MnCl₂ to

each tube. After 5 minutes, the reactions were stopped by the addition of 6 μ l of 95% formamide containing 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 15% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

5 After electrophoresis, the gel plates were separated allowing the gel to remain flat on one plate. A 0.2 mm-pore positively-charged nylon membrane (NYTRAN, Schleicher and Schuell, Keene, NH), pre-wetted in H₂O, was laid on top of the exposed gel. All air bubbles were removed. Two pieces of 3MM filter paper (Whatman) were then placed on top of the membrane, the other glass plate was replaced, and the sandwich was clamped with binder
10 clips. Transfer was allowed to proceed overnight. After transfer, the membrane was carefully peeled from the gel and allowed to air dry. After complete drying, the membrane was washed in 1.2X Sequenase Images Blocking Buffer (United States Biochemical) using 0.3 ml of buffer/cm² of membrane. The wash was performed for 30 minutes at room temperature. A streptavidin-alkaline phosphatase conjugate (SAAP, United States Biochemical) was added
15 to a 1:4000 dilution directly to the blocking solution, and agitated for 15 minutes. The membrane was rinsed briefly with H₂O and then washed three times for 5 minutes per wash using 0.5 ml/cm² of 1X SAAP buffer (100 mM Tris-HCl, pH 10, 50 mM NaCl) with 0.1% sodium dodecyl sulfate (SDS). The membrane was rinsed briefly with H₂O between each wash. The membrane was then washed once in 1X SAAP buffer containing 1 mM MgCl₂,
20 without SDS, drained thoroughly and placed in a plastic heat-sealable bag. Using a sterile pipet, 5 mls of CDP-Star™ (Tropix, Bedford, MA) chemiluminescent substrate for alkaline phosphatase were added to the bag and distributed over the entire membrane for 2-3 minutes. The CDP-Star™-treated membrane was exposed to XRP X-ray film (Kodak) for an initial exposure of 10 minutes.

25 The resulting autoradiograph is shown in Fig. 27. In Fig. 27, the lane labelled "M" contains the biotinylated P-15 oligonucleotide which served as a marker. The sizes (in nucleotides) of the uncleaved S-60 hairpin (60 nuc; lane 1), the marker (15 nuc; lane "M") and the cleavage products generated by cleavage of the S-60 hairpin in the presence (lane 3) or absence (lane 2) of the P-15 oligonucleotide are indicated.

30 Because the complementary regions of the S-60 hairpin are located on the same molecule, essentially no lag time should be needed to allow hybridization (*i.e.*, to form the duplex region of the hairpin). This hairpin structure would be expected to form long before the enzyme could locate and cleave the molecule. As expected, cleavage in the absence of the

primer oligonucleotide was at or near the junction between the duplex and single-stranded regions, releasing the unpaired 5' arm (Fig. 27, lane 2). The resulting cleavage products were 18 and 19 nucleotides in length.

It was expected that stability of the S-60 hairpin with the tri-loop would prevent the P-15 oligonucleotide from promoting cleavage in the "primer-directed" manner described in Example 1 above, because the 3' end of the "primer" would remain unpaired. Surprisingly, it was found that the enzyme seemed to mediate an "invasion" by the P-15 primer into the duplex region of the S-60 hairpin, as evidenced by the shifting of the cleavage site 3 to 4 basepairs further into the duplex region, releasing the larger products (22 and 21 nuc.) observed in lane 3 of Fig. 27.

The precise sites of cleavage of the S-60 hairpin are diagrammed on the structure in Fig. 26, with the solid black arrowheads indicating the sites of cleavage in the absence of the P-15 oligonucleotide and the hollow arrow heads indicating the sites of cleavage in the presence of P-15.

These data show that the presence on the 3' arm of an oligonucleotide having some sequence homology with the first several bases of the similarly oriented strand of the downstream duplex can be a dominant factor in determining the site of cleavage by 5' nucleases. Because the oligonucleotide which shares some sequence homology with the first several bases of the similarly oriented strand of the downstream duplex appears to invade the duplex region of the hairpin, it is referred to as an "invader" oligonucleotide. As shown in the examples below, an invader oligonucleotide appears to invade (or displace) a region of duplexed nucleic acid regardless of whether the duplex region is present on the same molecule (i.e., a hairpin) or whether the duplex is formed between two separate nucleic acid strands.

EXAMPLE 11

The Invader Oligonucleotide Shifts The Site Of Cleavage In A Pre-Formed Probe/Target Duplex

In Example 10 it was demonstrated that an invader oligonucleotide could shift the site at which a 5' nuclease cleaves a duplex region present on a hairpin molecule. In this example, the ability of an invader oligonucleotide to shift the site of cleavage within a duplex region formed between two separate strands of nucleic acid molecules was examined.

A single-stranded target DNA comprising the single-stranded circular M13mp19 molecule and a labeled (fluorescein) probe oligonucleotide were mixed in the presence of the reaction buffer containing salt (KCl) and divalent cations (Mg^{2+} or Mn^{2+}) to promote duplex formation. The probe oligonucleotide refers to a labelled oligonucleotide which is
5 complementary to a region along the target molecule (e.g., M13mp19). A second oligonucleotide (unlabelled) was added to the reaction after the probe and target had been allowed to anneal. The second oligonucleotide binds to a region of the target which is located downstream of the region to which the probe oligonucleotide binds. This second oligonucleotide contains sequences which are complementary to a second region of the target
10 molecule. If the second oligonucleotide contains a region which is complementary to a portion of the sequences along the target to which the probe oligonucleotide also binds, this second oligonucleotide is referred to as an invader oligonucleotide (see Fig. 28c).

Fig. 32 depicts the annealing of two oligonucleotides to regions along the M13mp19 target molecule (bottom strand in all three structures shown). In Fig. 28 only a 52 nucleotide
15 portion of the M13mp19 molecule is shown; this 52 nucleotide sequence is listed in SEQ ID NO:31. The probe oligonucleotide contains a fluorescein label at the 3' end; the sequence of the probe is 5'-AGAAAGGAAGGGAAGAAAGCGAAAGG-3' (SEQ ID NO:32). In Fig. 28, sequences comprising the second oligonucleotide, including the invader oligonucleotide are underlined. In Fig. 28a, the second oligonucleotide, which has the sequence
20 5'-GACGGGGAAAGCCGGCGAACG-3' (SEQ ID NO:33), is complementary to a different and downstream region of the target molecule than is the probe oligonucleotide (labeled with fluorescein or "Fluor"); there is a gap between the second, upstream oligonucleotide and the probe for the structure shown in Fig. 28a. In Fig. 28b, the second, upstream oligonucleotide, which has the sequence 5'-GAAAGCCGGCGAACGTGGCG-3' (SEQ ID NO:34), is
25 complementary to a different region of the target molecule than is the probe oligonucleotide, but in this case, the second oligonucleotide and the probe oligonucleotide abut one another (that is the 3' end of the second, upstream oligonucleotide is immediately adjacent to the 5' end of the probe such that no gap exists between these two oligonucleotides). In Fig. 28c, the second, upstream oligonucleotide [5'-GGCGAACGTGGCGAGAAAGGA-3' (SEQ ID
30 NO:35)] and the probe oligonucleotide share a region of complementarity with the target molecule. Thus, the upstream oligonucleotide has a 3' arm which has a sequence identical to the first several bases of the downstream probe. In this situation, the upstream oligonucleotide is referred to as an "invader" oligonucleotide.

The effect of the presence of an invader oligonucleotide upon the pattern of cleavage in a probe/target duplex formed prior to the addition of the invader was examined. The invader oligonucleotide and the enzyme were added after the probe was allowed to anneal to the target and the position and extent of cleavage of the probe were examined to determine a) if the invader was able to shift the cleavage site to a specific internal region of the probe, and b), if the reaction could accumulate specific cleavage products over time, even in the absence of thermal cycling, polymerization, or exonuclease removal of the probe sequence.

The reactions were carried out as follows. Twenty μ l each of two enzyme mixtures were prepared, containing 2 μ l of Cleavase® A/G nuclease extract (prepared as described in Example 2), with or without 50 pmole of the invader oligonucleotide (SEQ ID NO:35), as indicated, per 4 μ l of the mixture. For each of the eight reactions shown in Fig. 29, 150 fmole of M13mp19 single-stranded DNA (available from Life Technologies, Inc.) was combined with 5 pmoles of fluorescein labeled probe (SEQ ID NO:32), to create the structure shown in Fig. 28c, but without the invader oligonucleotide present (the probe/target mixture). One half (4 tubes) of the probe/target mixtures were combined with 1 μ l of 100 mM MOPS, pH 7.5 with 0.5% each of Tween-20 and NP-40, 0.5 μ l of 1 M KCl and 0.25 μ l of 80 mM $MnCl_2$, and distilled water to a volume of 6 μ l. The second set of probe/target mixtures were combined with 1 μ l of 100 mM MOPS, pH 7.5 with 0.5% each of Tween-20 and NP-40, 0.5 μ l of 1 M KCl and 0.25 μ l of 80 mM $MgCl_2$. The second set of mixtures therefore contained $MgCl_2$ in place of the $MnCl_2$ present in the first set of mixtures.

The mixtures (containing the probe/target with buffer, KCl and divalent cation) were covered with a drop of ChillOut® evaporation barrier and were brought to 60°C for 5 minutes to allow annealing. Four μ l of the above enzyme mixtures without the invader oligonucleotide was added to reactions whose products are shown in lanes 1, 3, 5 and 7 of Fig. 29. Reactions whose products are shown lanes 2, 4, 6, and 8 of Fig. 29 received the same amount of enzyme mixed with the invader oligonucleotide (SEQ ID NO:35). Reactions 1, 2, 5 and 6 were incubated for 5 minutes at 60°C and reactions 3, 4, 7 and 8 were incubated for 15 minutes at 60°C.

All reactions were stopped by the addition of 8 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90°C for 1 minute immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the reaction products and were visualized by the use of an Hitachi FMBIO fluorescence imager,

the output of which is seen in Fig. 29. The very low molecular weight fluorescent material seen in all lanes at or near the salt front in Fig. 29 and other fluoro-imager figures is observed when fluorescently-labeled oligonucleotides are electrophoresed and imaged on a fluoro-imager. This material is not a product of the cleavage reaction.

5 The use of $MnCl_2$ in these reactions (lanes 1-4) stimulates the true exonuclease or "nibbling" activity of the Cleavase® enzyme, as described in Example 6, as is clearly seen in lanes 1 and 3 of Fig. 29. This nibbling of the probe oligonucleotide (SEQ ID NO:32) in the absence of invader oligonucleotide (SEQ ID NO:35) confirms that the probe oligonucleotide is forming a duplex with the target sequence. The ladder-like products produced by this
10 nibbling reaction may be difficult to differentiate from degradation of the probe by nucleases that might be present in a clinical specimen. In contrast, introduction of the invader oligonucleotide (SEQ ID NO:35) caused a distinctive shift in the cleavage of the probe, pushing the site of cleavage 6 to 7 bases into the probe, confirming the annealing of both oligonucleotides. In presence of $MnCl_2$, the exonuclease "nibbling" may occur after the
15 invader-directed cleavage event, until the residual duplex is destabilized and falls apart.

In a magnesium based cleavage reaction (lanes 5-8), the nibbling or true exonuclease function of the Cleavase® A/G is enzyme suppressed (but the endonucleolytic function of the enzyme is essentially unaltered), so the probe oligonucleotide is not degraded in the absence of the invader (Fig. 29, lanes 5 and 7). When the invader is added, it is clear that the invader
20 oligonucleotide can promote a shift in the site of the endonucleolytic cleavage of the annealed probe. Comparison of the products of the 5 and 15 minute reactions with invader (lanes 6 and 8 in Fig. 29) shows that additional probe hybridizes to the target and is cleaved. The calculated melting temperature (T_m) of the portion of probe that is not invaded (*i.e.*, nucleotides 9-26 of SEQ ID NO:32) is 56°C, so the observed turnover (as evidenced by the
25 accumulation of cleavage products with increasing reaction time) suggests that the full length of the probe molecule, with a calculated T_m of 76°C, is must be involved in the subsequent probe annealing events in this 60°C reaction.

EXAMPLE 12

The Overlap Of The 3' Invader Oligonucleotide Sequence With
The 5' Region Of The Probe Causes A Shift In The Site Of Cleavage

5 In Example 11, the ability of an invader oligonucleotide to cause a shift in the site of
cleavage of a probe annealed to a target molecule was demonstrated. In this example,
experiments were conducted to examine whether the presence of an oligonucleotide upstream
from the probe was sufficient to cause a shift in the cleavage site(s) along the probe or
whether the presence of nucleotides on the 3' end of the invader oligonucleotide which have
10 the same sequence as the first several nucleotides at the 5' end of the probe oligonucleotide
were required to promote the shift in cleavage.

To examine this point, the products of cleavage obtained from three different
arrangements of target-specific oligonucleotides are compared. A diagram of these
oligonucleotides and the way in which they hybridize to a test nucleic acid, M13mp19, is
15 shown in Fig. 28. In Fig. 28a, the 3' end of the upstream oligonucleotide (SEQ ID NO:33) is
located upstream of the 5' end of the downstream "probe" oligonucleotide (SEQ ID NO:32)
such that a region of the M13 target which is not paired to either oligonucleotide is present.
In Fig. 28b, the sequence of the upstream oligonucleotide (SEQ ID NO:34) is immediately
upstream of the probe (SEQ ID NO:32), having neither a gap nor an overlap between the
20 sequences. Fig. 28c diagrams the arrangement of the substrates used in the assay of the
present invention, showing that the upstream "invader" oligonucleotide (SEQ ID NO:35) has
the same sequence on a portion of its 3' region as that present in the 5' region of the
downstream probe (SEQ ID NO:32). That is to say, these regions will compete to hybridize
to the same segment of the M13 target nucleic acid.

25 In these experiments, four enzyme mixtures were prepared as follows (planning 5 µl
per digest): Mixture 1 contained 2.25µl of Cleavase® A/G nuclease extract (prepared as
described in Example 2) per 5 µl of mixture, in 20 mM MOPS, pH 7.5 with 0.1 % each of
Tween 20 and NP-40, 4 mM MnCl₂ and 100 mM KCl. Mixture 2 contained 11.25 units of
Taq DNA polymerase (Promega) per 5 µl of mixture in 20 mM MOPS, pH 7.5 with 0.1 %
30 each of Tween 20 and NP-40, 4 mM MnCl₂ and 100 mM KCl. Mixture 3 contained 2.25 µl
of Cleavase® A/G nuclease extract per 5 µl of mixture in 20 mM Tris-HCl, pH 8.5, 4 mM
MgCl₂ and 100 mM KCl. Mixture 4 contained 11.25 units of *Taq* DNA polymerase per 5 µl
of mixture in 20 mM Tris-HCl, pH 8.5, 4 mM MgCl₂ and 100 mM KCl.

For each reaction, 50 fmole of M13mp19 single-stranded DNA (the target nucleic acid) was combined with 5 pmole of the probe oligonucleotide (SEQ ID NO:32 which contained a fluorescein label at the 3' end) and 50 pmole of one of the three upstream oligonucleotides diagrammed in Fig. 28 (*i.e.*, one of SEQ ID NOS:33-35), in a total volume of 5 μ l of distilled water. The reactions were overlaid with a drop of ChillOut™ evaporation barrier and warmed to 62°C. The cleavage reactions were started by the addition of 5 μ l of an enzyme mixture to each tube, and the reactions were incubated at 62°C for 30 min. The reactions shown in lanes 1-3 of Fig. 30 received Mixture 1; reactions 4-6 received Mixture 2; reactions 7-9 received Mixture 3 and reactions 10-12 received Mixture 4.

After 30 minutes at 62°C, the reactions were stopped by the addition of 8 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA.

Following electrophoresis, the products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, the output of which is seen in Fig. 30. The reaction products shown in lanes 1, 4, 7 and 10 of Fig. 30 were from reactions which contained SEQ ID NO:33 as the upstream oligonucleotide (see Fig. 28a). The reaction products shown in lanes 2, 5, 8 and 11 of Fig. 30 were from reactions which contained SEQ ID NO:34 as the upstream oligonucleotide (see Fig. 28b). The reaction products shown in lanes 3, 6, 9 and 12 of Fig. 30 were from reactions which contained SEQ ID NO:35, the invader oligonucleotide, as the upstream oligonucleotide (see Fig. 28c).

Examination of the Mn^{2+} based reactions using either Cleavase® A/G nuclease or DNAP Taq as the cleavage agent (lanes 1 through 3 and 4 through 6, respectively) shows that both enzymes have active exonuclease function in these buffer conditions. The use of a 3' label on the probe oligonucleotide allows the products of the nibbling activity to remain labeled, and therefore visible in this assay. The ladders seen in lanes 1, 2, 4 and 5 confirm that the probe hybridize to the target DNA as intended. These lanes also show that the location of the non-invasive oligonucleotides have little effect on the products generated. The uniform ladder created by these digests would be difficult to distinguish from a ladder caused by a contaminating nuclease, as one might find in a clinical specimen. In contrast, the products displayed in lanes 3 and 6, where an invader oligonucleotide was provided to direct the cleavage, show a very distinctive shift, so that the primary cleavage product is smaller than those seen in the non-invasive cleavage. This product is then subject to further nibbling

in these conditions, as indicated by the shorter products in these lanes. These invader-directed cleavage products would be easily distinguished from a background of non-specific degradation of the probe oligonucleotide.

When Mg^{2+} is used as the divalent cation the results are even more distinctive. In
5 lanes 7, 8, 10 and 11 of Fig. 30, where the upstream oligonucleotides were not invasive, minimal nibbling is observed. The products in the DNAP Taq reactions show some accumulation of probe that has been shortened on the 5' end by one or two nucleotides consistent with previous examination of the action of this enzyme on nicked substrates (Longley *et al.*, *supra*). When the upstream oligonucleotide is invasive, however, the
10 appearance of the distinctively shifted probe band is seen. These data clearly indicated that it is the invasive 3' portion of the upstream oligonucleotide that is responsible for fixing the site of cleavage of the downstream probe.

Thus, the above results demonstrate that it is the presence of the free or initially non-annealed nucleotides at the 3' end of the invader oligonucleotide which mediate the shift in
15 the cleavage site, not just the presence of an oligonucleotide annealed upstream of the probe. Nucleic acid detection assays which employ the use of an invader oligonucleotide are termed "invader-directed cleavage" assays.

EXAMPLE 13

20 Invader-Directed Cleavage Recognizes Single And Double Stranded
Target Molecules In A Background Of Non-Target DNA Molecules

For a nucleic acid detection method to be broadly useful, it must be able to detect a specific target in a sample that may contain large amounts of other DNA, *e.g.*, bacterial or
25 human chromosomal DNA. The ability of the invader directed cleavage assay to recognize and cleave either single- or double-stranded target molecules in the presence of large amounts of non-target DNA was examined. In these experiments a model target nucleic acid, M13, in either single or double stranded form (single-stranded M13mp18 is available from Life Technologies, Inc and double-stranded M13mp19 is available from New England Biolabs),
30 was combined with human genomic DNA (Novagen, Madison, WI) and then utilized in invader-directed cleavage reactions. Before the start of the cleavage reaction, the DNAs were heated to 95°C for 15 minutes to completely denature the samples, as is standard practice in

assays, such as polymerase chain reaction or enzymatic DNA sequencing, which involve solution hybridization of oligonucleotides to double-stranded target molecules.

For each of the reactions shown in lanes 2-5 of Fig. 31, the target DNA (25 fmole of the ss DNA or 1 pmole of the ds DNA) was combined with 50 pmole of the invader oligonucleotide (SEQ ID NO:35); for the reaction shown in lane 1 the target DNA was omitted. Reactions 1, 3 and 5 also contained 470 ng of human genomic DNA. These mixtures were brought to a volume of 10 μ l with distilled water, overlaid with a drop of ChillOut™ evaporation barrier, and brought to 95°C for 15 minutes. After this incubation period, and still at 95°C, each tube received 10 μ l of a mixture comprising 2.25 μ l of Cleavase® A/G nuclease extract (prepared as described in Example 2) and 5 pmole of the probe oligonucleotide (SEQ ID NO:32), in 20 mM MOPS, pH 7.5 with 0.1 % each of Tween 20 and NP-40, 4 mM MnCl₂ and 100 mM KCl. The reactions were brought to 62°C for 15 minutes and stopped by the addition of 12 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager. The results are displayed in Fig. 31.

In Fig. 31, lane 1 contains the products of the reaction containing the probe (SEQ ID NO:32), the invader oligonucleotide (SEQ ID NO:35) and human genomic DNA. Examination of lane 1 shows that the probe and invader oligonucleotides are specific for the target sequence, and that the presence of genomic DNA does not cause any significant background cleavage.

In Fig. 31, lanes 2 and 3 contain reaction products from reactions containing the single-stranded target DNA (M13mp18), the probe (SEQ ID NO:32) and the invader oligonucleotide (SEQ ID NO:35) in the absence or presence of human genomic DNA, respectively. Examination of lanes 2 and 3 demonstrate that the invader detection assay may be used to detect the presence of a specific sequence on a single-stranded target molecule in the presence or absence of a large excess of competitor DNA (human genomic DNA).

In Fig. 31, lanes 4 and 5 contain reaction products from reactions containing the double-stranded target DNA (M13mp19), the probe (SEQ ID NO:32) and the invader oligonucleotide (SEQ ID NO:35) in the absence or presence of human genomic DNA, respectively. Examination of lanes 4 and 5 show that double stranded target molecules are eminently suitable for invader-directed detection reactions. The success of this reaction using

a short duplexed molecule. M13mp19, as the target in a background of a large excess of genomic DNA is especially noteworthy as it would be anticipated that the shorter and less complex M13 DNA strands would be expected to find their complementary strand more easily than would the strands of the more complex human genomic DNA. If the M13 DNA reannealed before the probe and/or invader oligonucleotides could bind to the target sequences along the M13 DNA, the cleavage reaction would be prevented. In addition, because the denatured genomic DNA would potentially contain regions complementary to the probe and/or invader oligonucleotides it was possible that the presence of the genomic DNA would inhibit the reaction by binding these oligonucleotides thereby preventing their hybridization to the M13 target. The above results demonstrate that these theoretical concerns are not a problem under the reaction conditions employed above.

In addition to demonstrating that the invader detection assay may be used to detect sequences present in a double-stranded target, these data also show that the presence of a large amount of non-target DNA (470 ng/20 μ l reaction) does not lessen the specificity of the cleavage. While this amount of DNA does show some impact on the rate of product accumulation, probably by binding a portion of the enzyme, the nature of the target sequence, whether single- or double-stranded nucleic acid, does not limit the application of this assay.

EXAMPLE 14

Signal Accumulation In The Invader-Directed Cleavage Assay As A Function Of Target Concentration

To investigate whether the invader-directed cleavage assay could be used to indicate the amount of target nucleic acid in a sample, the following experiment was performed.

Cleavage reactions were assembled which contained an invader oligonucleotide (SEQ ID NO:35), a labelled probe (SEQ ID NO:32) and a target nucleic acid, M13mp19. A series of reactions, which contained smaller and smaller amounts of the M13 target DNA, was employed in order to examine whether the cleavage products would accumulate in a manner that reflected the amount of target DNA present in the reaction.

The reactions were conducted as follows. A master mix containing enzyme and buffer was assembled. Each 5 μ l of the master mixture contained 25 ng of Cleavase® BN nuclease in 20 mM MOPS (pH 7.5) with 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$ and 100 mM KCl. For each of the cleavage reactions shown in lanes 4-13 of Fig. 32, a DNA mixture

was generated which contained 5 pmoles of the fluorescein-labelled probe oligonucleotide (SEQ ID NO:32), 50 pmoles of the invader oligonucleotide (SEQ ID NO:35) and 100, 50, 10, 5, 1, 0.5, 0.1, 0.05, 0.01 or 0.005 fmoles of single-stranded M13mp19, respectively, for every 5 μ l of the DNA mixture. The DNA solutions were covered with a drop of ChillOut[®] evaporation barrier and brought to 61°C. The cleavage reactions were started by the addition of 5 μ l of the enzyme mixture to each of tubes (final reaction volume was 10 μ l). After 30 minutes at 61°C, the reactions were terminated by the addition of 8 μ l of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90°C for 1 minutes immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. To provide reference (*i.e.*, standards), 1.0, 0.1 and 0.01 pmole aliquots of fluorescein-labelled probe oligonucleotide (SEQ ID NO:32) were diluted with the above formamide solution to a final volume of 18 μ l. These reference markers were loaded into lanes 1-3, respectively of the gel. The products of the cleavage reactions (as well as the reference standards) were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. The results are displayed in Fig. 32.

In Fig. 32, boxes appear around fluorescein-containing nucleic acid (*i.e.*, the cleaved and uncleaved probe molecules) and the amount of fluorescein contained within each box is indicated under the box. The background fluorescence of the gel (see box labelled "background") was subtracted by the fluoro-imager to generate each value displayed under a box containing cleaved or uncleaved probe products (the boxes are numbered 1-14 at top left with a V followed by a number below the box). The lane marked "M" contains fluoresceinated oligonucleotides which served as markers.

The results shown in Fig. 32, demonstrate that the accumulation of cleaved probe molecules in a fixed-length incubation period reflects the amount of target DNA present in the reaction. The results also demonstrate that the cleaved probe products accumulate in excess of the copy number of the target. This is clearly demonstrated by comparing the results shown in lane 3, in which 10 fmole (0.01 pmole) of uncut probe are displayed with the results shown in 5, where the products which accumulated in response to the presence of 10 fmole of target DNA are displayed. These results show that the reaction can cleave hundreds of probe oligonucleotide molecules for each target molecule present, dramatically amplifying the target-specific signal generated in the invader-directed cleavage reaction.

EXAMPLE 15

Effect Of Saliva Extract On The Invader-Directed Cleavage Assay

For a nucleic acid detection method to be useful in a medical (*i.e.*, a diagnostic) setting, it must not be inhibited by materials and contaminants likely to be found in a typical clinical specimen. To test the susceptibility of the invader-directed cleavage assay to various materials, including but not limited to nucleic acids, glycoproteins and carbohydrates, likely to be found in a clinical sample, a sample of human saliva was prepared in a manner consistent with practices in the clinical laboratory and the resulting saliva extract was added to the invader-directed cleavage assay. The effect of the saliva extract upon the inhibition of cleavage and upon the specificity of the cleavage reaction was examined.

One and one-half milliliters of human saliva were collected and extracted once with an equal volume of a mixture containing phenol:chloroform:isoamyl alcohol (25:24:1). The resulting mixture was centrifuged in a microcentrifuge to separate the aqueous and organic phases. The upper, aqueous phase was transferred to a fresh tube. One-tenth volumes of 3 M NaOAc were added and the contents of the tube were mixed. Two volumes of 100% ethyl alcohol were added to the mixture and the sample was mixed and incubated at room temperature for 15 minutes to allow a precipitate to form. The sample was centrifuged in a microcentrifuge at 13,000 rpm for 5 minutes and the supernatant was removed and discarded. A milky pellet was easily visible. The pellet was rinsed once with 70% ethanol, dried under vacuum and dissolved in 200 μ l of 10 mM Tris-HCl, pH 8.0, 0.1 mM EDTA (this constitutes the saliva extract). Each μ l of the saliva extract was equivalent to 7.5 μ l of saliva. Analysis of the saliva extract by scanning ultraviolet spectrophotometry showed a peak absorbance at about 260 nm and indicated the presence of approximately 45 ng of total nucleic acid per μ l of extract.

The effect of the presence of saliva extract upon the following enzymes was examined: Cleavase® BN nuclease, Cleavase® A/G nuclease and three different lots of DNAPtaq: AmpliTaq® (Perkin Elmer: a recombinant form of DNAPtaq), AmpliTaq® LD (Perkin-Elmer: a recombinant DNAPtaq preparation containing very low levels of DNA) and Taq DNA polymerase (Fischer). For each enzyme tested, an enzyme/probe mixture was made comprising the chosen amount of enzyme with 5 pmole of the probe oligonucleotide (SEQ ID NO:32) in 10 μ l of 20 mM MOPS (pH 7.5) containing 0.1% each of Tween 20 and NP-40, 4 mM $MnCl_2$, 100 mM KCl and 100 μ g/ml BSA. The following amounts of enzyme were

used: 25 ng of Cleavase® BN prepared as described in Example 8; 2 µl of Cleavase® A/G nuclease extract prepared as described in Example 2; 2.25 µl (11.25 polymerase units) the following DNA polymerases: AmpliTaq® DNA polymerase (Perkin Elmer); AmpliTaq® DNA polymerase LD (low DNA; from Perkin Elmer); *Taq* DNA polymerase (Fisher Scientific).

For each of the reactions shown in Fig. 33, except for that shown in lane 1, the target DNA (50 fmoles of single-stranded M13mp19 DNA) was combined with 50 pmole of the invader oligonucleotide (SEQ ID NO:35) and 5 pmole of the probe oligonucleotide (SEQ ID NO:32); target DNA was omitted in reaction 1 (lane 1). Reactions 1, 3, 5, 7, 9 and 11 included 1.5 µl of saliva extract. These mixtures were brought to a volume of 5 µl with distilled water, overlaid with a drop of ChillOut® evaporation barrier and brought to 95°C for 10 minutes. The cleavage reactions were then started by the addition of 5 µl of the desired enzyme/probe mixture: reactions 1, 4 and 5 received Cleavase® A/G nuclease. Reactions 2 and 3 received Cleavase® BN; reactions 6 and 7 received AmpliTaq®; reactions 8 and 9 received AmpliTaq® LD; and reactions 10 and 11 received *Taq* DNA Polymerase from Fisher Scientific.

The reactions were incubated at 63°C for 30 minutes and were stopped by the addition of 6 µl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, and the results are displayed in Fig. 33.

A pairwise comparison of the lanes shown in Fig. 33 without and with the saliva extract, treated with each of the enzymes, shows that the saliva extract has different effects on each of the enzymes. While the Cleavase® BN nuclease and the AmpliTaq® are significantly inhibited from cleaving in these conditions, the Cleavase® A/G nuclease and AmpliTaq® LD display little difference in the yield of cleaved probe. The preparation of *Taq* DNA polymerase from Fisher Scientific shows an intermediate response, with a partial reduction in the yield of cleaved product. From the standpoint of polymerization, the three DNAPTaq variants should be equivalent; these should be the same protein with the same amount of synthetic activity. It is possible that the differences observed could be due to variations in the amount of nuclease activity present in each preparation caused by different handling during purification, or by different purification protocols. In any case, quality control assays

designed to assess polymerization activity in commercial DNAP preparations would be unlikely to reveal variation in the amount of nuclease activity present. If preparations of DNAPtaq were screened for full 5' nuclease activity (*i.e.* if the 5' nuclease activity was specifically quantitated), it is likely that the preparations would display sensitivities (to saliva extract) more in line with that observed using Cleavase® A/G nuclease, from which DNAPtaq differs by a very few amino acids.

It is worthy of note that even in the slowed reactions of Cleavase® BN and the DNAPtaq variants there is no noticeable increase in non-specific cleavage of the probe oligonucleotide due to inappropriate hybridization or saliva-borne nucleases.

EXAMPLE 16

Comparison Of Additional 5' Nucleases In The Invader-Directed Cleavage Assay

A number of eubacterial Type A DNA polymerases (*i.e.* Pol I type DNA polymerases) have been shown to function as structure specific endonucleases (Example 1 and Lyamichev *et al.* *supra*). In this example, it was demonstrated that the enzymes of this class can also be made to catalyze the invader-directed cleavage of the present invention, albeit not as efficiently as the Cleavase® enzymes.

Cleavase® BN nuclease and Cleavase® A/G nuclease were tested along side three different thermostable DNA polymerases: *Thermus aquaticus* DNA polymerase (Promega), *Thermus thermophilus* and *Thermus flavus* DNA polymerases (Epicentre). The enzyme mixtures used in the reactions shown in lanes 1-11 of Fig. 34 contained the following, each in a volume of 5 µl: Lane 1: 20 mM MOPS (pH 7.5) with 0.1% each of Tween 20 and NP-40, 4 mM MnCl₂, 100 mM KCl; Lane 2: 25 ng of Cleavase® BN nuclease in the same solution described for lane 1; Lane 3: 2.25 µl of Cleavase® A/G nuclease extract (prepared as described in Example 2), in the same solution described for lane 1; Lane 4: 2.25 µl of Cleavase® A/G nuclease extract in 20 mM Tris-Cl, (pH 8.5), 4 mM MgCl₂ and 100 mM KCl; Lane 5: 11.25 polymerase units of *Taq* DNA polymerase in the same buffer described for lane 4; Lane 6: 11.25 polymerase units of *Tth* DNA polymerase in the same buffer described for lane 1; Lane 7: 11.25 polymerase units of *Tth* DNA polymerase in a 2X concentration of the buffer supplied by the manufacturer, supplemented with 4 mM MnCl₂; Lane 8: 11.25 polymerase units of *Tth* DNA polymerase in a 2X concentration of the buffer supplied by the

manufacturer, supplemented with 4 mM MgCl₂; Lane 9: 2.25 polymerase units of *Tfl* DNA polymerase in the same buffer described for lane 1; Lane 10: 2.25 polymerase units of *Tfl* polymerase in a 2X concentration of the buffer supplied by the manufacturer, supplemented with 4 mM MnCl₂; Lane 11: 2.25 polymerase units of *Tfl* DNA polymerase in a 2X concentration of the buffer supplied by the manufacturer, supplemented with 4 mM MgCl₂.

Sufficient target DNA, probe and invader for all 11 reactions was combined into a master mix. This mix contained 550 fmoles of single-stranded M13mp19 target DNA, 550 pmoles of the invader oligonucleotide (SEQ ID NO:35) and 55 pmoles of the probe oligonucleotide (SEQ ID NO:32), each as depicted in Fig. 28c, in 55 µl of distilled water. Five µl of the DNA mixture was dispensed into each of 11 labeled tubes and overlaid with a drop of ChillOut® evaporation barrier. The reactions were brought to 63°C and cleavage was started by the addition of 5 µl of the appropriate enzyme mixture. The reaction mixtures were then incubated at 63°C temperature for 15 minutes. The reactions were stopped by the addition of 8 µl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 90°C for 1 minute immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. Following electrophoresis, the products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager, and the results are displayed in Fig. 34. Examination of the results shown in Fig. 34 demonstrates that all of the 5' nucleases tested have the ability to catalyze invader-directed cleavage in at least one of the buffer systems tested. Although not optimized here, these cleavage agents are suitable for use in the methods of the present invention.

EXAMPLE 17

The Invader-Directed Cleavage Assay Can Detect Single Base Differences In Target Nucleic Acid Sequences

The ability of the invader-directed cleavage assay to detect single base mismatch mutations was examined. Two target nucleic acid sequences containing Cleavase® enzyme-resistant phosphorothioate backbones were chemically synthesized and purified by polyacrylamide gel electrophoresis. Targets comprising phosphorothioate backbones were used to prevent exonucleolytic nibbling of the target when duplexed with an oligonucleotide. A target oligonucleotide, which provides a target sequence that is completely complementary

to the invader oligonucleotide (SEQ ID NO:35) and the probe oligonucleotide (SEQ ID NO:32), contained the following sequence:

5'-CCTTTTCGCTTTCTTCCCTTCCTTTCTCGCCACGTTTCGCCGGC-3' (SEQ ID NO:36). A

second target sequence containing a single base change relative to SEQ ID NO:36 was

5 synthesized: 5'-CCTTTTCGCT**CT**TTTCCCTTCCTTTCTCGCCACGTTTCGCCGGC-3 (SEQ ID NO:37; the single base change relative to SEQ ID NO:36 is shown using bold and underlined type). The consequent mismatch occurs within the "Z" region of the target as represented in Fig. 25.

To discriminate between two target sequences which differ by the presence of a single mismatch), invader-directed cleavage reactions were conducted using two different reaction temperatures (55°C and 60°C). Mixtures containing 200 fmoles of either SEQ ID NO:36 or SEQ ID NO:37, 3 pmoles of fluorescein-labelled probe oligonucleotide (SEQ ID NO:32), 7.7 pmoles of invader oligonucleotide (SEQ ID NO:35) and 2 µl of Cleavase® A/G nuclease extract (prepared as described in Example 2) in 9 µl of 10 mM MOPS (pH 7.4) with 50 mM KCl were assembled, covered with a drop of ChillOut® evaporation barrier and brought to the appropriate reaction temperature. The cleavage reactions were initiated by the addition of 1 µl of 20 mM MgCl₂. After 30 minutes at either 55°C or 60°C, 10 µl of 95% formamide with 20 mM EDTA and 0.05% marker dyes was added to stop the reactions. The reaction mixtures were then heated to 90°C for one minute prior to loading 4 µl onto 20% denaturing polyacrylamide gels. The resolved reaction products were visualized using a Hitachi FMBIO fluorescence imager. The resulting image is shown in Fig. 35.

In Fig. 35, lanes 1 and 2 show the products from reactions conducted at 55°C; lanes 3 and 4 show the products from reactions conducted at 60°C. Lanes 1 and 3 contained products from reactions containing SEQ ID NO:36 (perfect match to probe) as the target. Lanes 2 and 4 contained products from reactions containing SEQ ID NO:37 (single base mis-match with probe) as the target. The target that does not have a perfect hybridization match (*i.e.*, complete complementarity) with the probe will not bind as strongly, *i.e.*, the T_m of that duplex will be lower than the T_m of the same region if perfectly matched. The results presented here show that reaction conditions can be varied to either accommodate the mis-match (*e.g.*, by lowering the temperature of the reaction) or to exclude the binding of the mis-matched sequence (*e.g.*, by raising the reaction temperature).

The results shown in Fig. 35 demonstrate that the specific cleavage event which occurs in invader-directed cleavage reactions can be eliminated by the presence of a single base mis-

match between the probe oligonucleotide and the target sequence. Thus, reaction conditions can be chosen so as to exclude the hybridization of mis-matched invader-directed cleavage probes thereby diminishing or even eliminating the cleavage of the probe. In an extension of this assay system, multiple cleavage probes, each possessing a separate reporter molecule (*i.e.*, a unique label), could also be used in a single cleavage reaction, to simultaneously probe for two or more variants in the same target region. The products of such a reaction would allow not only the detection of mutations which exist within a target molecule, but would also allow a determination of the relative concentrations of each sequence (*i.e.*, mutant and wild type or multiple different mutants) present within samples containing a mixture of target sequences. When provided in equal amounts, but in a vast excess (*e.g.*, at least a 100-fold molar excess; typically at least 1 pmole of each probe oligonucleotide would be used when the target sequence was present at about 10 fmoles or less) over the target and used in optimized conditions. As discussed above, any differences in the relative amounts of the target variants will not affect the kinetics of hybridization, so the amounts of cleavage of each probe will reflect the relative amounts of each variant present in the reaction.

The results shown in the example clearly demonstrate that the invader-directed cleavage reaction can be used to detect single base difference between target nucleic acids.

EXAMPLE 18

The Invader-Directed Cleavage Reaction Is Insensitive To Large Changes In Reaction Conditions

The results shown above demonstrated that the invader-directed cleavage reaction can be used for the detection of target nucleic acid sequences and that this assay can be used to detect single base difference between target nucleic acids. These results demonstrated that 5' nucleases (*e.g.*, Cleavase®BN, Cleavase® A/G, DNAPTaq, DNAPTth, DNAPTfl) could be used in conjunction with a pair of overlapping oligonucleotides as an efficient way to recognize nucleic acid targets. In the experiments below it is demonstrated that invasive cleavage reaction is relatively insensitive to large changes in conditions thereby making the method suitable for practice in clinical laboratories.

The effects of varying the conditions of the cleavage reaction were examined for their effect(s) on the specificity of the invasive cleavage and the on the amount of signal accumulated in the course of the reaction. To compare variations in the cleavage reaction a

"standard" invader cleavage reaction was first defined. In each instance, unless specifically stated to be otherwise, the indicated parameter of the reaction was varied, while the invariant aspects of a particular test were those of this standard reaction. The results of these tests are either shown in Figs. 38-40, or the results described below.

5

a) The Standard Invader-Directed Cleavage Reaction

The standard reaction was defined as comprising 1 fmole of M13mp18 single-stranded target DNA (New England Biolabs), 5 pmoles of the labeled probe oligonucleotide (SEQ ID NO:38), 10 pmole of the upstream invader oligonucleotide (SEQ ID NO:39) and 2 units of
10 Cleavase® A/G in 10 µl of 10 mM MOPS, pH 7.5 with 100 mM KCl, 4 mM MnCl₂, and 0.05% each Tween-20 and Nonidet-P40. For each reaction, the buffers, salts and enzyme were combined in a volume of 5 µl; the DNAs (target and two oligonucleotides) were combined in 5 µl of dH₂O and overlaid with a drop of ChillOut® evaporation barrier. When multiple reactions were performed with the same reaction constituents, these formulations
15 were expanded proportionally.

Unless otherwise stated, the sample tubes with the DNA mixtures were warmed to 61°C, and the reactions were started by the addition of 5 µl of the enzyme mixture. After 20 minutes at this temperature, the reactions were stopped by the addition of 8 µl of 95% formamide with 20 mM EDTA and 0.05% marker dyes. Samples were heated to 75°C for 2
20 minutes immediately before electrophoresis through a 20% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The products of the reactions were visualized by the use of an Hitachi FMBIO fluorescence imager. In each case, the uncut probe material was visible as an intense black band or blob, usually in the top half of the panel, while the desired products of invader specific cleavage were visible as one
25 or two narrower black bands, usually in the bottom half of the panel. Under some reaction conditions, particularly those with elevated salt concentrations, a secondary cleavage product is also visible (thus generating a doublet). Ladders of lighter grey bands generally indicate either exonuclease nibbling of the probe oligonucleotide or heat-induced, non-specific breakage of the probe.

30 Fig. 37 depicts the annealing of the probe and invader oligonucleotides to regions along the M13mp18 target molecule (the bottom strand). In Fig. 37 only a 52 nucleotide portion of the M13mp18 molecule is shown; this 52 nucleotide sequence is listed in SEQ ID NO:31 (this sequence is identical in both M13mp18 and M13mp19). The probe

oligonucleotide (top strand) contains a Cy3 amidite label at the 5' end; the sequence of the probe is 5'-AGAAAGGAAGGGAAGAAAGCGAAAGGT-3' (SEQ ID NO:38). The bold type indicates the presence of a modified base (2'-O-CH₃). Cy3 amidite (Pharmacia) is a indodicarbocyanine dye amidite which can be incorporated at any position during the synthesis of oligonucleotides; Cy3 fluoresces in the yellow region (excitation and emission maximum of 554 and 568 nm, respectively). The invader oligonucleotide (middle strand) has the following sequence: 5'-GCCGGCGAACGTGGCGAGAAAGGA-3' (SEQ ID NO:39).

b) KCl Titration

Fig. 38 shows the results of varying the KCl concentration in combination with the use of 2 mM MnCl₂ in an otherwise standard reaction. The reactions were performed in duplicate for confirmation of observations; the reactions shown in lanes 1 and 2 contained no added KCl, lanes 3 and 4 contained KCl at 5 mM, lanes 5 and 6 contained 25 mM KCl, lanes 7 and 8 contained 50 mM KCl, lanes 9 and 10 contained 100 mM KCl and lanes 11 and 12 contained 200 mM KCl. These results show that the inclusion of KCl allows the generation of a specific cleavage product. While the strongest signal is observed at the 100 mM KCl concentration, the specificity of signal in the other reactions with KCl at or above 25 mM indicates that concentrations in the full range (*i.e.*, 25-200 mM) may be chosen if it is so desirable for any particular reaction conditions.

As shown in Fig. 38, the invader-directed cleavage reaction requires the presence of salt (*e.g.*, KCl) for effective cleavage to occur. In other reactions, it has been found that KCl can inhibit the activity of certain Cleavase[®] enzymes when present at concentrations above about 25 mM (For example, in cleavage reactions using the S-60 oligonucleotide shown in Fig. 26, in the absence of primer, the Cleavase[®] BN enzyme loses approximately 50% of its activity in 50 mM KCl). Therefore, the use of alternative salts in the invader-directed cleavage reaction was examined. In these experiments, the potassium ion was replaced with either Na⁺ or Li⁺ or the chloride ion was replaced with glutamic acid. The replacement of KCl with alternative salts is described below in sections c-e.

c) NaCl Titration

NaCl was used in place of KCl at 75, 100, 150 or 200 mM, in combination with the use of 2 mM MnCl₂ in an otherwise standard reaction. These results showed that NaCl can be used as a replacement for KCl in the invader-directed cleavage reaction, with like

concentration giving like results. (*i.e.*, the presence of NaCl, like KCl, enhances product accumulation).

d) LiCl Titration

LiCl was used in place of KCl in otherwise standard reactions. Concentrations tested were 25, 50, 75, 100, 150 and 200mM LiCl. The results demonstrated that LiCl can be used as a suitable replacement for KCl in the invader-directed cleavage reaction (*i.e.*, the presence of LiCl, like KCl, enhances product accumulation), in concentrations of about 100 mM or higher.

e) KGlu Titration

The results of using a glutamate salt of potassium (KGlu) in place of the more commonly used chloride salt (KCl) in reactions performed over a range of temperatures were examined. KGlu has been shown to be a highly effective salt source for some enzymatic reactions, showing a broader range of concentrations which permit maximum enzymatic activity [Leirimo *et al.* (1987) Biochem. 26:2095]. The ability of KGlu to facilitate the annealing of the probe and invader oligonucleotides to the target nucleic acid was compared to that of LiCl. In these experiments, the reactions were run for 15 minutes, rather than the standard 20 minutes, in standard reactions that replaced KCl 200 mM, 300 mM or 400 mM KGlu. The reactions were run at 65°C, 67°C, 69°C or 71°C. The results showed demonstrated that KGlu was very effective as a salt in the invasive cleavage reactions, with full activity apparent even at 400 mM KGlu, though at the lowest temperature cleavage was reduced by about 30% at 300 mM KGlu, and by about 90% to 400 mM KGlu.

f) MnCl₂ And MgCl₂ Titration And Ability To Replace MnCl₂ With MgCl₂

In some instances it may be desirable to perform the invasive cleavage reaction in the presence of Mg²⁺, either in addition to, or in place of Mn²⁺ as the necessary divalent cation required for activity of the enzyme employed. For example, some common methods of preparing DNA from bacterial cultures or tissues use MgCl₂ in solutions which are used to facilitate the collection of DNA by precipitation. In addition, elevated concentrations (*i.e.*, greater than 5 mM) of divalent cation can be used to facilitate hybridization of nucleic acids. in the same way that the monovalent salts were used above, thereby enhancing the invasive

cleavage reaction. In this experiment, the tolerance of the invasive cleavage reaction was examined for 1) the substitution of MgCl_2 for MnCl_2 and for the ability to produce specific product in the presence of increasing concentrations of MgCl_2 and MnCl_2 .

Fig. 39 shows the results of either varying the concentration of MnCl_2 from 2 mM to 8 mM, replacing the MnCl_2 with MgCl_2 at 2 to 4 mM, or of using these components in combination in an otherwise standard reaction. The reactions analyzed in lanes 1 and 2 contained 2 mM each MnCl_2 and MgCl_2 , lanes 3 and 4 contained 2 mM MnCl_2 only, lanes 5 and 6 contained 3 mM MnCl_2 , lanes 7 and 8 contained 4 mM MnCl_2 , lanes 9 and 10 contained 8 mM MnCl_2 . The reactions analyzed in lanes 11 and 12 contained 2 mM MgCl_2 and lanes 13 and 14 contained 4 mM MgCl_2 . These results show that both MnCl_2 and MgCl_2 can be used as the necessary divalent cation to enable the cleavage activity of the Cleavase[®] A/G enzyme in these reactions and that the invasive cleavage reaction can tolerate a broad range of concentrations of these components.

In addition to examining the effects of the salt environment on the rate of product accumulation in the invasive cleavage reaction, the use of reaction constituents shown to be effective in enhancing nucleic acid hybridization in either standard hybridization assays (*e.g.*, blot hybridization) or in ligation reactions was examined. These components may act as volume excluders, increasing the effective concentration of the nucleic acids of interest and thereby enhancing hybridization, or they may act as charge-shielding agents to minimize repulsion between the highly charged backbones of the nucleic acids strands. The results of these experiments are described in sections g and h below.

g) Effect Of CTAB Addition

The polycationic detergent cetyltriethylammonium bromide (CTAB) has been shown to dramatically enhance hybridization of nucleic acids [Pontius and Berg (1991) Proc. Natl. Acad. Sci. USA 88:8237]. We examined the effect of adding the detergent CTAB in concentrations from 100 mM to 1 mM to invasive cleavage reactions in which 150 mM LiCl was used in place of the KCl in otherwise standard reactions. These results showed that 200 mM CTAB may have a very moderate enhancing effect under these reaction conditions, and the presence of CTAB in excess of about 500 μM was inhibitory to the accumulation of specific cleavage product.

h) Effect Of PEG Addition

We examined the effect of adding polyethylene glycol (PEG) at 4.8 or 12% (w/v) concentrations to otherwise standard reactions. The effects of increasing the reaction temperature of the PEG-containing reactions was examined by performing duplicate sets of PEG titration reactions at 61°C and 65°C. The results showed that at all percentages tested, and at both temperatures tested, the inclusion of PEG substantially eliminated the production of specific cleavage product.

In addition to, the presence of 1X Denhardt's in the reaction mixture was found to have no adverse effect upon the cleavage reaction [50X Denhardt's contains per 500 ml: 5 g Ficoll, 5 g polyvinylpyrrolidone, 5 g BSA]. Further, the presence of each component of Denhardt's was examined individually (*i.e.*, Ficoll alone, polyvinylpyrrolidone alone, BSA alone) for the effect upon the invader-directed cleavage reaction; no adverse effect was observed.

i) Effect Of The Addition Of Stabilizing Agents

Another approach to enhancing the output of the invasive cleavage reaction is to enhance the activity of the enzyme employed, either by increasing its stability in the reaction environment or by increasing its turnover rate. Without regard to the precise mechanism by which various agents operate in the invasive cleavage reaction, a number of agents commonly used to stabilize enzymes during prolonged storage were tested for the ability to enhance the accumulation of specific cleavage product in the invasive cleavage reaction.

We examined the effects of adding glycerol at 15% and of adding the detergents Tween-20 and Nonidet-P40 at 1.5%, alone or in combination, in otherwise standard reactions. The results demonstrated that under these conditions these adducts had little or no effect on the accumulation of specific cleavage product.

The effects of adding gelatin to reactions in which the salt identity and concentration were varied from the standard reaction. The results demonstrated that in the absence of salt the gelatin had a moderately enhancing effect on the accumulation of specific cleavage product, but when either salt (KCl or LiCl) was added to reactions performed under these conditions, increasing amounts of gelatin reduced the product accumulation.

j) **Effect Of Adding Large Amounts Of Non-Target Nucleic Acid**

In detecting specific nucleic acid sequences within samples, it is important to determine if the presence of additional genetic material (*i.e.*, non-target nucleic acids) will have a negative effect on the specificity of the assay. In this experiment, the effect of including large amounts of non-target nucleic acid, either DNA or RNA, on the specificity of the invasive cleavage reaction was examined. The data was examined for either an alteration in the expected site of cleavage, or for an increase in the nonspecific degradation of the probe oligonucleotide.

Fig. 40 shows the effects of adding non-target nucleic acid (*e.g.*, genomic DNA or tRNA) to an invasive cleavage reaction performed at 65°C, with 150 mM LiCl in place of the KCl in the standard reaction. The reactions assayed in lanes 1 and 2 contained 235 and 470 ng of genomic DNA, respectively. The reactions analyzed in lanes 3, 4, 5 and 6 contained 100 ng, 200 ng, 500 ng and 1 µg of tRNA, respectively. Lane 7 represents a control reaction which contained no added nucleic acid beyond the amounts used in the standard reaction. The results shown in Fig. 40 demonstrate that the inclusion of non-target nucleic acid in large amounts could visibly slow the accumulation of specific cleavage product (while not limiting the invention to any particular mechanism, it is thought that the additional nucleic acid competes for binding of the enzyme with the specific reaction components). In additional experiments it was found that the effect of adding large amounts of non-target nucleic acid can be compensated for by increasing the enzyme in the reaction. The data shown in Fig. 40 also demonstrate that a key feature of the invasive cleavage reaction, the specificity of the detection, was not compromised by the presence of large amounts of non-target nucleic acid.

In addition to the data presented above, invasive cleavage reactions were run with succinate buffer at pH 5.9 in place of the MOPS buffer used in the "standard" reaction; no adverse effects were observed.

The data shown in Figs. 38-40 and described above demonstrate that the invasive cleavage reaction can be performed using a wide variety of reaction conditions and is therefore suitable for practice in clinical laboratories.

EXAMPLE 19

Detection Of RNA Targets By Invader-Directed Cleavage

5 In addition to the clinical need to detect specific DNA sequences for infectious and genetic diseases, there is a need for technologies that can quantitatively detect target nucleic acids that are composed of RNA. For example, a number of viral agents, such as hepatitis C virus (HCV) and human immunodeficiency virus (HIV) have RNA genomic material, the quantitative detection of which can be used as a measure of viral load in a patient sample. Such information can be of critical diagnostic or prognostic value.

10 Hepatitis C virus (HCV) infection is the predominant cause of post-transfusion non-A, non-B (NANB) hepatitis around the world. In addition, HCV is the major etiologic agent of hepatocellular carcinoma (HCC) and chronic liver disease world wide. The genome of HCV is a small (9.4 kb) RNA molecule. In studies of transmission of HCV by blood transfusion it has been found the presence of HCV antibody, as measured in standard immunological tests, 15 does not always correlate with the infectivity of the sample, while the presence of HCV RNA in a blood sample strongly correlates with infectivity. Conversely, serological tests may remain negative in immunosuppressed infected individuals, while HCV RNA may be easily detected [J.A. Cuthbert (1994) *Clin. Microbiol. Rev.* 7:505].

The need for and the value of developing a probe-based assay for the detection the 20 HCV RNA is clear. The polymerase chain reaction has been used to detect HCV in clinical samples, but the problems associated with carry-over contamination of samples has been a concern. Direct detection of the viral RNA without the need to perform either reverse transcription or amplification would allow the elimination of several of the points at which existing assays may fail.

25 The genome of the positive-stranded RNA hepatitis C virus comprises several regions including 5' and 3' noncoding regions (i.e., 5' and 3' untranslated regions) and a polyprotein coding region which encodes the core protein (C), two envelope glycoproteins (E1 and E2/NS1) and six nonstructural glycoproteins (NS2-NS5b). Molecular biological analysis of the HCV genome has showed that some regions of the genome are very highly conserved 30 between isolates, while other regions are fairly rapidly changeable. The 5' noncoding region (NCR) is the most highly conserved region in the HCV. These analyses have allowed these viruses to be divided into six basic genotype groups, and then further classified into over a

dozen sub-types [the nomenclature and division of HCV genotypes is evolving; see Altamirano *et al.*, *J. Infect. Dis.* 171:1034 (1995) for a recent classification scheme].

In order to develop a rapid and accurate method of detecting HCV present in infected individuals, the ability of the invader-directed cleavage reaction to detect HCV RNA was
 5 examined. Plasmids containing DNA derived from the conserved 5'-untranslated region of six different HCV RNA isolates were used to generate templates for *in vitro* transcription. The HCV sequences contained within these six plasmids represent genotypes 1 (four sub-types represented; 1a, 1b, 1c, and Δ 1c), 2, and 3. The nomenclature of the HCV genotypes used herein is that of Simmonds *et al.* [as described in Altamirano *et al.*, *supra*]. The Δ 1c subtype
 10 was used in the model detection reaction described below.

a) Generation Of Plasmids Containing HCV Sequences

Six DNA fragments derived from HCV were generated by RT-PCR using RNA extracted from serum samples of blood donors; these PCR fragments were a gift of Dr. M.
 15 Altamirano (University of British Columbia, Vancouver). These PCR fragments represent HCV sequences derived from HCV genotypes 1a, 1b, 1c, Δ 1c, 2c and 3a.

The RNA extraction, reverse transcription and PCR were performed using standard techniques (Altamirano *et al.*, *supra*). Briefly, RNA was extracted from 100 μ l of serum using guanidine isothiocyanate, sodium lauryl sarkosate and phenol-chloroform [Inchauspe *et al.*, *Hepatology* 14:595 (1991)]. Reverse transcription was performed according to the
 20 manufacturer's instructions using a GeneAmp rTh reverse transcriptase RNA PCR kit (Perkin-Elmer) in the presence of an external antisense primer, HCV342. The sequence of the HCV342 primer is 5'-GGTTTTCTTTGAGGTTAG-3' (SEQ ID NO:40). Following termination of the RT reaction, the sense primer HCV7 [5'-GCGACACTCCACCATAGAT-3' (SEQ ID NO:41)] and magnesium were added and a first PCR was performed. Aliquots of
 25 the first PCR products were used in a second (nested) PCR in the presence of primers HCV46 [5'-CTGTCTTCACGCAGAAAGC-3' (SEQ ID NO:42)] and HCV308 [5'-GCACGGTCTACGAGACCTC-3' (SEQ ID NO:43)]. The PCRs produced a 281 bp product which corresponds to a conserved 5' noncoding region (NCR) region of HCV between positions -
 30 284 and -4 of the HCV genome (Altamirano *et al.*, *supra*).

The six 281 bp PCR fragments were used directly for cloning or they were subjected to an additional amplification step using a 50 μ l PCR comprising approximately 100 fmoles of DNA, the HCV46 and HCV308 primers at 0.1 μ M, 100 μ M of all four dNTPs and 2.5

units of *Taq* DNA polymerase in a buffer containing 10 mM Tris-HCl, pH 8.3, 50 mM KCl, 1.5 mM MgCl₂, and 0.1% Tween 20. The PCRs were cycled 25 times at 96°C for 45 sec., 55°C for 45 sec. and 72°C for 1 min. Two microliters of either the original DNA samples or the reamplified PCR products were used for cloning in the linear pT7Blue T-vector (Novagen) according to manufacturer's protocol. After the PCR products were ligated to the pT7Blue T-vector, the ligation reaction mixture was used to transform competent JM109 cells (Promega). Clones containing the pT7Blue T-vector with an insert were selected by the presence of colonies having a white color on LB plates containing 40 µg/ml X-Gal, 40 µg/ml IPTG and 50 µg/ml ampicillin. Four colonies for each PCR sample were picked and grown overnight in 2 ml LB media containing 50 µg/ml carbenicillin. Plasmid DNA was isolated using the following alkaline miniprep protocol. Cells from 1.5 ml of the overnight culture were collected by centrifugation for 2 min. in a microcentrifuge (14K rpm), the supernatant was discarded and the cell pellet was resuspended in 50 µl TE buffer with 10 µg/ml RNase A (Pharmacia). One hundred microliters of a solution containing 0.2 N NaOH, 1% SDS was added and the cells were lysed for 2 min. The lysate was gently mixed with 100 µl of 1.32 M potassium acetate, pH 4.8, and the mixture was centrifuged for 4 min. in a microcentrifuge (14K rpm); the pellet comprising cell debris was discarded. Plasmid DNA was precipitated from the supernatant with 200 µl ethanol and pelleted by centrifugation a microcentrifuge (14K rpm). The DNA pellet was air dried for 15 min. and was then redissolved in 50 µl TE buffer (10 mM Tris-HCl, pH 7.8, 1 mM EDTA).

**b) Reamplification Of HCV Clones To Add The Phage T7
Promoter For Subsequent *In Vitro* Transcription**

To ensure that the RNA product of transcription had a discrete 3' end it was necessary to create linear transcription templates which stopped at the end of the HCV sequence. These fragments were conveniently produced using the PCR to reamplify the segment of the plasmid containing the phage promoter sequence and the HCV insert. For these studies, the clone of HCV type Δ1c was reamplified using a primer that hybridizes to the T7 promoter sequence: 5'-TAATACGACTCACTATAGGG-3' (SEQ ID NO:44; "the T7 promoter primer") (Novagen) in combination with the 3' terminal HCV-specific primer HCV308 (SEQ ID NO:43). For these reactions, 1 µl of plasmid DNA (approximately 10 to 100 ng) was reamplified in a 200 µl PCR using the T7 and HCV308 primers as described above with the exception that 30 cycles of amplification were employed. The resulting amplicon was 354 bp

in length. After amplification the PCR mixture was transferred to a fresh 1.5 ml microcentrifuge tube. the mixture was brought to a final concentration of 2 M NH_4OAc . and the products were precipitated by the addition of one volume of 100% isopropanol. Following a 10 min. incubation at room temperature. the precipitates were collected by centrifugation. washed once with 80% ethanol and dried under vacuum. The collected material was dissolved in 100 μl nuclease-free distilled water (Promega).

Segments of RNA were produced from this amplicon by *in vitro* transcription using the RiboMAX™ Large Scale RNA Production System (Promega) in accordance with the manufacturer's instructions, using 5.3 μg of the amplicon described above in a 100 μl reaction. The transcription reaction was incubated for 3.75 hours. after which the DNA template was destroyed by the addition of 5-6 μl of RQ1 RNase-free DNase (1 unit/ μl) according to the RiboMAX™ kit instructions. The reaction was extracted twice with phenol/chloroform/isoamyl alcohol (50:48:2) and the aqueous phase was transferred to a fresh microcentrifuge tube. The RNA was then collected by the addition of 10 μl of 3M NH_4OAc . pH 5.2 and 110 μl of 100% isopropanol. Following a 5 min. incubation at 4°C. the precipitate was collected by centrifugation, washed once with 80% ethanol and dried under vacuum. The sequence of the resulting RNA transcript (HCV1.1 transcript) is listed in SEQ ID NO:45.

c) Detection Of The HCV1.1 Transcript In The Invader-Directed Cleavage Assay

Detection of the HCV1.1 transcript was tested in the invader-directed cleavage assay using an HCV-specific probe oligonucleotide [5'-CCGGTCGTCCTGGCAATXCC-3' (SEQ ID NO:46): X indicates the presence of a fluorescein dye on an abasic linker) and an HCV-specific invader oligonucleotide [5'-GTTTATCCAAGAAAGGACCCGGTC-3' (SEQ ID NO:47)] that causes a 6-nucleotide invasive cleavage of the probe.

Each 10 μl of reaction mixture comprised 5 pmole of the probe oligonucleotide (SEQ ID NO:46) and 10 pmole of the invader oligonucleotide (SEQ ID NO:47) in a buffer of 10 mM MOPS, pH 7.5 with 50 mM KCl, 4 mM MnCl_2 , 0.05% each Tween-20 and Nonidet-P40 and 7.8 units RNasin® ribonuclease inhibitor (Promega). The cleavage agents employed were Cleavase® A/G (used at 5.3 ng/10 μl reaction) or DNAPTth (used at 5 polymerase units/10 μl reaction). The amount of RNA target was varied as indicated below. When RNase treatment is indicated. the target RNAs were pre-treated with 10 μg of RNase A (Sigma) at 37°C for 30 min. to demonstrate that the detection was specific for the RNA in the reaction and not due to

the presence of any residual DNA template from the transcription reaction. RNase-treated aliquots of the HCV RNA were used directly without intervening purification.

For each reaction, the target RNAs were suspended in the reaction solutions as described above, but lacking the cleavage agent and the $MnCl_2$ for a final volume of 10 μ l, with the invader and probe at the concentrations listed above. The reactions were warmed to 46°C and the reactions were started by the addition of a mixture of the appropriate enzyme with $MnCl_2$. After incubation for 30 min. at 46°C, the reactions were stopped by the addition of 8 μ l of 95% formamide, 10 mM EDTA and 0.02% methyl violet (methyl violet loading buffer). Samples were then resolved by electrophoresis through a 15% denaturing polyacrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scan shown in Fig. 41.

In Fig. 41, the samples analyzed in lanes 1-4 contained 1 pmole of the RNA target, the reactions shown in lanes 5-8 contained 100 fmoles of the RNA target and the reactions shown in lanes 9-12 contained 10 fmoles of the RNA target. All odd-numbered lanes depict reactions performed using Cleavase® A/G enzyme and all even-numbered lanes depict reactions performed using DNAPTth. The reactions analyzed in lanes 1, 2, 5, 6, 9 and 10 contained RNA that had been pre-digested with RNase A. These data demonstrate that the invasive cleavage reaction efficiently detects RNA targets and further, the absence of any specific cleavage signal in the RNase-treated samples confirms that the specific cleavage product seen in the other lanes is dependent upon the presence of input RNA.

EXAMPLE 20

The Fate Of The Target RNA In The Invader-Directed Cleavage Reaction

In this example, the fate of the RNA target in the invader-directed cleavage reaction was examined. As shown above in Example 1D, when RNAs are hybridized to DNA oligonucleotides, the 5' nucleases associated with DNA polymerases can be used to cleave the RNAs; such cleavage can be suppressed when the 5' arm is long or when it is highly structured [Lyamichev *et al.* (1993) *Science* 260:778 and U.S. Patent No. 5,422,253, the disclosure of which is herein incorporated by reference]. In this experiment, the extent to

which the RNA target would be cleaved by the cleavage agents when hybridized to the detection oligonucleotides (*i.e.*, the probe and invader oligonucleotides) was examined using reactions similar to those described in Example 20, performed using fluorescein-labeled RNA as a target.

5 Transcription reactions were performed as described in Example 19 with the exception that 2% of the UTP in the reaction was replaced with fluorescein-12-UTP (Boehringer Mannheim) and 5.3 µg of the amplicon was used in a 100 µl reaction. The transcription reaction was incubated for 2.5 hours, after which the DNA template was destroyed by the addition of 5-6 µl of RQ1 RNase-free DNase (1 unit/µl) according to the RiboMAX™ kit
10 instructions. The organic extraction was omitted and the RNA was collected by the addition of 10 µl of 3M NaOAc, pH 5.2 and 110 µl of 100% isopropanol. Following a 5 min. incubation at 4°C, the precipitate was collected by centrifugation, washed once with 80% ethanol and dried under vacuum. The resulting RNA was dissolved in 100 µl of nuclease-free water. 50% of the sample was purified by electrophoresis through a 8% denaturing
15 polyacrylamide gel (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. The gel slice containing the full-length material was excised and the RNA was eluted by soaking the slice overnight at 4°C in 200 µl of 10 mM Tris-Cl, pH 8.0, 0.1 mM EDTA and 0.3 M NaOAc. The RNA was then precipitated by the addition of 2.5 volumes of 100% ethanol. After incubation at -20°C for 30 min., the
20 precipitates were recovered by centrifugation, washed once with 80% ethanol and dried under vacuum. The RNA was dissolved in 25 µl of nuclease-free water and then quantitated by UV absorbance at 260 nm.

 Samples of the purified RNA target were incubated for 5 or 30 min. in reactions that duplicated the Cleavase[®] A/G and DNAPT[®] invader reactions described in Example 20 with
25 the exception that the reactions lacked probe and invader oligonucleotides. Subsequent analysis of the products showed that the RNA was very stable, with a very slight background of non-specific degradation, appearing as a gray background in the gel lane. The background was not dependent on the presence of enzyme in the reaction.

 Invader detection reactions using the purified RNA target were performed using the
30 probe/invader pair described in Example 19 (SEQ ID NOS:46 and 47). Each reaction included 500 fmole of the target RNA, 5 pmoles of the fluorescein-labeled probe and 10 pmoles of the invader oligonucleotide in a buffer of 10 mM MOPS, pH 7.5 with 150 mM LiCl, 4 mM MnCl₂, 0.05% each Tween-20 and Nonidet-P40 and 39 units RNasin[®].

(Promega). These components were combined and warmed to 50°C and the reactions were started by the addition of either 53 ng of Cleavase® A/G or 5 polymerase units of DNAPTth. The final reaction volume was 10 µl. After 5 min at 50°C, 5 µl aliquots of each reaction were removed to tubes containing 4 µl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The remaining aliquot received a drop of ChillOut® evaporation barrier and was incubated for an additional 25 min. These reactions were then stopped by the addition of 4 µl of the above formamide solution. The products of these reactions were resolved by electrophoresis through separate 20% denaturing polyacrylamide gels (19:1 cross-linked), containing 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Following electrophoresis, the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scans shown in Figs. 42A (5 min reactions) and 42B (30 min. reactions).

In Fig. 53 the target RNA is seen very near the top of each lane, while the labeled probe and its cleavage products are seen just below the middle of each panel. The FMBIO-100 Image Analyzer was used to quantitate the fluorescence signal in the probe bands. In each panel, lane 1 contains products from reactions performed in the absence of a cleavage agent, lane 2 contains products from reactions performed using Cleavase® A/G and lane 3 contains products from reactions performed using DNAPTth.

Quantitation of the fluorescence signal in the probe bands revealed that after a 5 min. incubation, 12% or 300 fmole of the probe was cleaved by the Cleavase® A/G and 29% or 700 fmole was cleaved by the DNAPTth. After a 30 min. incubation, Cleavase® A/G had cleaved 32% of the probe molecules and DNAPTth had cleaved 70% of the probe molecules. (The images shown in Figs. 42A and 42B were printed with the intensity adjusted to show the small amount of background from the RNA degradation, so the bands containing strong signals are saturated and therefore these images do not accurately reflect the differences in measured fluorescence)

The data shown in Fig. 42 clearly shows that, under invasive cleavage conditions, RNA molecules are sufficiently stable to be detected as a target and that each RNA molecule can support many rounds of probe cleavage.

EXAMPLE 21

Titration Of Target RNA In
The Invader-Directed Cleavage Assay

5 One of the primary benefits of the invader-directed cleavage assay as a means for detection of the presence of specific target nucleic acids is the correlation between the amount of cleavage product generated in a set amount of time and the quantity of the nucleic acid of interest present in the reaction. The benefits of quantitative detection of RNA sequences was discussed in Example 19. In this example, we demonstrate the quantitative nature of the
10 detection assay through the use of various amounts of target starting material. In addition to demonstrating the correlation between the amounts of input target and output cleavage product, these data graphically show the degree to which the RNA target can be recycled in this assay

The RNA target used in these reactions was the fluorescein-labeled material described
15 in Example 20 (*i.e.*, SEQ ID NO:45). Because the efficiency of incorporation of the fluorescein-12-UTP by the T7 RNA polymerase was not known, the concentration of the RNA was determined by measurement of absorbance at 260 nm, not by fluorescence intensity. Each reaction comprised 5 pmoles of the fluorescein-labeled probe (SEQ ID NO:46) and 10 pmoles of the invader oligonucleotide (SEQ ID NO:47) in a buffer of 10 mM MOPS, pH 7.5
20 with 150 mM LiCl, 4 mM MnCl₂, 0.05% each Tween-20 and Nonidet-P40 and 39 units of RNAsin[®] (Promega). The amount of target RNA was varied from 1 to 100 fmoles, as indicated below. These components were combined, overlaid with ChillOut[®] evaporation barrier and warmed to 50°C; the reactions were started by the addition of either 53 ng of Cleavase[®] A/G or 5 polymerase units of DNAPTth, to a final reaction volume of 10 µl. After
25 30 minutes at 50°C, reactions were stopped by the addition of 8 µl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The unreacted markers in lanes 1 and 2 were diluted in the same total volume (18 µl). The samples were heated to 90°C for 1 minute and 2.5 µl of each of these reactions were resolved by electrophoresis through a 20% denaturing polyacrylamide gel (19:1 cross link) with 7M urea in a buffer of 45 mM Tris-Borate, pH 8.3.
30 1.4 mM EDTA, and the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi), with the resulting imager scans shown in Fig. 43.

In Fig. 43, lanes 1 and 2 show 5 pmoles of uncut probe and 500 fmoles of untreated RNA, respectively. The probe is the very dark signal near the middle of the panel, while the

RNA is the thin line near the top of the panel. These RNAs were transcribed with a 2% substitution of fluorescein-12-UTP for natural UTP in the transcription reaction. The resulting transcript contains 74 U residues, which would give an average of 1.5 fluorescein labels per molecule. With one tenth the molar amount of RNA loaded in lane 2, the signal in lane 2 should be approximately one seventh (0.15X) the fluorescence intensity of the probe in lane 1. Measurements indicated that the intensity was closer to one fortieth, indicating an efficiency of label incorporation of approximately 17%. Because the RNA concentration was verified by A260 measurement this does not alter the experimental observations below, but it should be noted that the signal from the RNA and the probes does not accurately reflect the relative amounts in the reactions.

The reactions analyzed in lanes 3 through 7 contained 1, 5, 10, 50 and 100 fmoles of target, respectively, with cleavage of the probe accomplished by Cleavase[®] A/G. The reactions analyzed in lanes 8 through 12 repeated the same array of target amounts, with cleavage of the probe accomplished by DNAPTth. The boxes seen surrounding the product bands show the area of the scan in which the fluorescence was measured for each reaction. The number of fluorescence units detected within each box is indicated below each box; background fluorescence was also measured.

It can be seen by comparing the detected fluorescence in each lane that the amount of product formed in these 30 minute reactions can be correlated to the amount of target material. The accumulation of product under these conditions is slightly enhanced when DNAPTth is used as the cleavage agent, but the correlation with the amount of target present remains. This demonstrates that the invader assay can be used as a means of measuring the amount of target RNA within a sample.

Comparison of the fluorescence intensity of the input RNA with that of the cleaved product shows that the invader-directed cleavage assay creates signal in excess of the amount of target, so that the signal visible as cleaved probe is far more intense than that representing the target RNA. This further confirms the results described in Example 20, in which it was demonstrated that each RNA molecule could be used many times.

EXAMPLE 22

Detection Of DNA By Charge Reversal

The detection of specific targets is achieved in the invader-directed cleavage assay by
5 the cleavage of the probe oligonucleotide. In addition to the methods described in the
preceding examples, the cleaved probe may be separated from the uncleaved probe using the
charge reversal technique described below. This novel separation technique is related to the
observation that positively charged adducts can affect the electrophoretic behavior of small
oligonucleotides because the charge of the adduct is significant relative to charge of the whole
10 complex. Observations of aberrant mobility due to charged adducts have been reported in the
literature, but in all cases found, the applications pursued by other scientists have involved
making oligonucleotides larger by enzymatic extension. As the negatively charged
nucleotides are added on, the positive influence of the adduct is reduced to insignificance. As
a result, the effects of positively charged adducts have been dismissed and have received
15 infinitesimal notice in the existing literature.

This observed effect is of particular utility in assays based on the cleavage of DNA
molecules. When an oligonucleotide is shortened through the action of a Cleavase[®] enzyme
or other cleavage agent, the positive charge can be made to not only significantly reduce the
net negative charge, but to actually override it, effectively "flipping" the net charge of the
20 labeled entity. This reversal of charge allows the products of target-specific cleavage to be
partitioned from uncleaved probe by extremely simple means. For example, the products of
cleavage can be made to migrate towards a negative electrode placed at any point in a
reaction vessel, for focused detection without gel-based electrophoresis. When a slab gel is
used, sample wells can be positioned in the center of the gel, so that the cleaved and
25 uncleaved probes can be observed to migrate in opposite directions. Alternatively, a
traditional vertical gel can be used, but with the electrodes reversed relative to usual DNA
gels (*i.e.*, the positive electrode at the top and the negative electrode at the bottom) so that the
cleaved molecules enter the gel, while the uncleaved disperse into the upper reservoir of
electrophoresis buffer.

30 An additional benefit of this type of readout is that the absolute nature of the partition
of products from substrates means that an abundance of uncleaved probe can be supplied to
drive the hybridization step of the probe-based assay, yet the unconsumed probe can be
subtracted from the result to reduce background.

Through the use of multiple positively charged adducts, synthetic molecules can be constructed with sufficient modification that the normally negatively charged strand is made nearly neutral. When so constructed, the presence or absence of a single phosphate group can mean the difference between a net negative or a net positive charge. This observation has particular utility when one objective is to discriminate between enzymatically generated fragments of DNA, which lack a 3' phosphate, and the products of thermal degradation, which retain a 3' phosphate (and thus two additional negative charges).

**a) Characterization Of The Products Of Thermal Breakage Of
DNA Oligonucleotides**

Thermal degradation of DNA probes results in high background which can obscure signals generated by specific enzymatic cleavage, decreasing the signal-to-noise ratio. To better understand the nature of DNA thermal degradation products, we incubated the 5' tetrachloro-fluorescein (TET)-labeled oligonucleotides 78 (SEQ ID NO:48) and 79 (SEQ ID NO:49) (100 pmole each) in 50 μ l 10 mM NaCO₃ (pH 10.6), 50 mM NaCl at 90°C for 4 hours. To prevent evaporation of the samples, the reaction mixture was overlaid with 50 μ l of ChillOut[®] liquid wax. The reactions were then divided in two equal aliquots (A and B). Aliquot A was mixed with 25 μ l of methyl violet loading buffer and Aliquot B was dephosphorylated by addition of 2.5 μ l of 100 mM MgCl₂ and 1 μ l of 1 unit/ μ l Calf Intestinal Alkaline Phosphatase (CIAP) (Promega), with incubation at 37°C for 30 min. after which 25 μ l of methyl violet loading buffer was added. One microliter of each sample was resolved by electrophoresis through a 12% polyacrylamide denaturing gel and imaged as described in Example 21: a 585 nm filter was used with the FMBIO Image Analyzer. The resulting imager scan is shown in Fig. 44.

In Fig. 44, lanes 1-3 contain the TET-labeled oligonucleotide 78 and lanes 4-6 contain the TET-labeled oligonucleotides 79. Lanes 1 and 4 contain products of reactions which were not heat treated. Lanes 2 and 5 contain products from reactions which were heat treated and lanes 3 and 6 contain products from reactions which were heat treated and subjected to phosphatase treatment.

As shown in Fig. 44, heat treatment causes significant breakdown of the 5'-TET-labeled DNA, generating a ladder of degradation products (Fig. 44, lanes 2, 3, 5 and 6). Band intensities correlate with purine and pyrimidine base positioning in the oligonucleotide sequences, indicating that backbone hydrolysis may occur through formation of abasic

intermediate products that have faster rates for purines than for pyrimidines [Lindahl and Karlström (1973) Biochem. 12:5151].

Dephosphorylation decreases the mobility of all products generated by the thermal degradation process, with the most pronounced effect observed for the shorter products (Fig. 44, lanes 3 and 6). This demonstrates that thermally degraded products possess a 3' end terminal phosphoryl group which can be removed by dephosphorylation with CIAP. Removal of the phosphoryl group decreases the overall negative charge by 2. Therefore, shorter products which have a small number of negative charges are influenced to a greater degree upon the removal of two charges. This leads to a larger mobility shift in the shorter products than that observed for the larger species.

The fact that the majority of thermally degraded DNA products contain 3' end phosphate groups and Cleavase® enzyme-generated products do not allowed the development of simple isolation methods for products generated in the invader-directed cleavage assay. The extra two charges found in thermal breakdown products do not exist in the specific cleavage products. Therefore, if one designs assays that produce specific products which contain a net positive charge of one or two, then similar thermal breakdown products will either be negative or neutral. The difference can be used to isolate specific products by reverse charge methods as shown below.

**b) Dephosphorylation Of Short Amino-Modified
Oligonucleotides Can Reverse The Net Charge Of The
Labeled Product**

To demonstrate how oligonucleotides can be transformed from net negative to net positively charged compounds, the four short amino-modified oligonucleotides labeled 70, 74, 75 and 76 and shown in Figs. 45-47 were synthesized (Fig. 45 shows both oligonucleotides 70 and 74). All four modified oligonucleotides possess Cy-3 dyes positioned at the 5'-end which individually are positively charged under reaction and isolation conditions described in this example. Compounds 70 and 74 contain two amino modified thymidines that, under reaction conditions, display positively charged $R-NH_3^+$ groups attached at the C5 position through a C_{10} or C_6 linker, respectively. Because compounds 70 and 74 are 3'-end phosphorylated, they consist of four negative charges and three positive charges. Compound 75 differs from 74 in that the internal C_6 amino modified thymidine phosphate in 74 is replaced by a thymidine methyl phosphonate. The phosphonate backbone is uncharged and so

there are a total of three negative charges on compound 75. This gives compound 75 a net negative one charge. Compound 76 differs from 70 in that the internal amino modified thymidine is replaced by an internal cytosine phosphonate. The pK_a of the N3 nitrogen of cytosine can be from 4 to 7. Thus, the net charges of this compound, can be from -1 to 0 depending on the pH of the solution. For the simplicity of analysis, each group is assigned a whole number of charges, although it is realized that, depending on the pK_a of each chemical group and ambient pH, a real charge may differ from the whole number assigned. It is assumed that this difference is not significant over the range of pHs used in the enzymatic reactions studied here.

Dephosphorylation of these compounds, or the removal of the 3' end terminal phosphoryl group, results in elimination of two negative charges and generates products that have a net positive charge of one. In this experiment, the method of isoelectric focusing (IEF) was used to demonstrate a change from one negative to one positive net charge for the described substrates during dephosphorylation.

Substrates 70, 74, 75 and 76 were synthesized by standard phosphoramidite chemistries and deprotected for 24 hours at 22°C in 14 M aqueous ammonium hydroxide solution, after which the solvent was removed in vacuo. The dried powders were resuspended in 200 μ l of H_2O and filtered through 0.2 μ m filters. The concentration of the stock solutions was estimated by UV-absorbance at 261 nm of samples diluted 200-fold in H_2O using a spectrophotometer (Spectronic Genesys 2, Milton Roy, Rochester, NY).

Dephosphorylation of compounds 70 and 74, 75 and 76 was accomplished by treating 10 μ l of the crude stock solutions (ranging in concentration from approximately 0.5 to 2 mM) with 2 units of CIAP in 100 μ l of CIAP buffer (Promega) at 37°C for 1 hour. The reactions were then heated to 75°C for 15 min. in order to inactivate the CIAP. For clarity, dephosphorylated compounds are designated 'dp'. For example, after dephosphorylation, substrate 70 becomes 70dp.

To prepare samples for IEF experiments, the concentration of the stock solutions of substrate and dephosphorylated product were adjusted to a uniform absorbance of 8.5×10^{-3} at 532 nm by dilution with water. Two microliters of each sample were analyzed by IEF using a PhastSystem electrophoresis unit (Pharmacia) and PhastGel IEF 3-9 media (Pharmacia) according to the manufacturer's protocol. Separation was performed at 15°C with the following program: pre-run: 2,000 V, 2.5 mA, 3.5 W, 75 Vh; load: 200 V, 2.5 mA, 3.5 W, 15 Vh; run: 2,000 V, 2.5 mA, 3.5 W, 130 Vh. After separation, samples were visualized by

using the FMBIO Image Analyzer (Hitachi) fitted with a 585 nm filter. The resulting imager scan is shown in Fig. 48.

Fig. 48 shows results of IEF separation of substrates 70, 74, 75 and 76 and their dephosphorylated products. The arrow labeled "Sample Loading Position" indicates a loading line, the '+' sign shows the position of the positive electrode and the '-' sign indicates the position of the negative electrode.

The results shown in Fig. 48 demonstrate that substrates 70, 74, 75 and 76 migrated toward the positive electrode, while the dephosphorylated products 70dp, 74dp, 75dp and 76dp migrated toward negative electrode. The observed differences in mobility direction was in accord with predicted net charge of the substrates (minus one) and the products (plus one). Small perturbations in the mobilities of the phosphorylated compounds indicate that the overall pIs vary. This was also true for the dephosphorylated compounds. The presence of the cytosine in 76dp, for instance, moved this compound further toward the negative electrode which was indicative of a higher overall pi relative to the other dephosphorylated compounds. It is important to note that additional positive charges can be obtained by using a combination of natural amino modified bases (70dp and 74dp) along with uncharged methylphosphonate bridges (products 75dp and 76dp).

The results shown above demonstrate that the removal of a single phosphate group can flip the net charge of an oligonucleotide to cause reversal in an electric field, allowing easy separation of products, and that the precise base composition of the oligonucleotides affect absolute mobility but not the charge-flipping effect.

EXAMPLE 23

Detection Of Specific Cleavage Products In The Invader-Directed Cleavage Reaction By Charge Reversal

In this example the ability to isolate products generated in the invader-directed cleavage assay from all other nucleic acids present in the reaction cocktail was demonstrated using charge reversal. This experiment utilized the following Cy3-labeled oligonucleotide: 5'-Cy3-AminoT-AminoT-CTTTTCACCAGCGAGACGGG-3' (SEQ ID NO:50; termed "oligo 61"). Oligo 61 was designed to release upon cleavage a net positively charged labeled product. To test whether or not a net positively charged 5'-end labeled product would be recognized by the Cleavase® enzymes in the invader-directed cleavage assay format, probe

oligo 61 (SEQ ID NO:50) and invading oligonucleotide 67 (SEQ ID NO:51) were chemically synthesized on a DNA synthesizer (ABI 391) using standard phosphoramidite chemistries and reagents obtained from Glen Research (Sterling, VA).

Each assay reaction comprised 100 fmoles of M13mp18 single stranded DNA, 10 pmoles each of the probe (SEQ ID NO:50) and Invader™ (SEQ ID NO:51) oligonucleotides, and 20 units of Cleavase® A/G in a 10 µl solution of 10 mM MOPS, pH 7.4 with 100 mM KCl. Samples were overlaid with mineral oil to prevent evaporation. The samples were brought to either 50°C, 55°C, 60°C, or 65°C and cleavage was initiated by the addition of 1 µl of 40 mM MnCl₂. Reactions were allowed to proceed for 25 minutes and then were terminated by the addition of 10 µl of 95% formamide containing 20 mM EDTA and 0.02% methyl violet. The negative control experiment lacked the target M13mp18 and was run at 60°C. Five microliters of each reaction were loaded into separate wells of a 20% denaturing polyacrylamide gel (cross-linked 29:1) with 8 M urea in a buffer containing 45 mM Tris-Borate (pH 8.3) and 1.4 mM EDTA. An electric field of 20 watts was applied for 30 minutes, with the electrodes oriented as indicated in Fig. 49B (*i.e.*, in reverse orientation). The products of these reactions were visualized using the FMBIO fluorescence imager and the resulting imager scan is shown in Fig. 49B.

Fig. 49A provides a schematic illustration showing an alignment of the invader (SEQ ID NO:50) and probe (SEQ ID NO:51) along the target M13mp18 DNA; only 53 bases of the M13mp18 sequence is shown (SEQ ID NO:52). The sequence of the invader oligonucleotide is displayed under the M13mp18 target and an arrow is used above the M13mp18 sequence to indicate the position of the invader relative to the probe and target. As shown in Fig. 49A, the invader and probe oligonucleotides share a 2 base region of overlap.

In Fig. 49B, lanes 1-6 contain reactions performed at 50°C, 55°C, 60°C, and 65°C, respectively; lane 5 contained the control reaction (lacking target). In Fig. 49B, the products of cleavage are seen as dark bands in the upper half of the panel; the faint lower band seen appears in proportion to the amount of primary product produced and, while not limiting the invention to a particular mechanism, may represent cleavage one nucleotide into the duplex. The uncleaved probe does not enter the gel and is thus not visible. The control lane showed no detectable signal over background (lane 5). As expected in an invasive cleavage reaction, the rate of accumulation of specific cleavage product was temperature-dependent. Using these particular oligonucleotides and target, the fastest rate of accumulation of product was observed at 55°C (lane 2) and very little product observed at 65°C (lane 4).

When incubated for extended periods at high temperature, DNA probes can break non-specifically (*i.e.*, suffer thermal degradation) and the resulting fragments contribute an interfering background to the analysis. The products of such thermal breakdown are distributed from single-nucleotides up to the full length probe. In this experiment, the ability of charge based separation of cleavage products (*i.e.*, charge reversal) would allow the sensitive separation of the specific products of target-dependent cleavage from probe fragments generated by thermal degradation was examined.

To test the sensitivity limit of this detection method, the target M13mp18 DNA was serially diluted ten fold over than range of 1 fmole to 1 amole. The invader and probe oligonucleotides were those described above (*i.e.*, SEQ ID NOS:50 and 51). The invasive cleavage reactions were run as described above with the following modifications: the reactions were performed at 55°C, 250 mM or 100 mM KGlu was used in place of the 100 mM KCl and only 1 pmole of the invader oligonucleotide was added. The reactions were initiated as described above and allowed to progress for 12.5 hours. A negative control reaction which lacked added M13mp18 target DNA was also run. The reactions were terminated by the addition of 10 µl of 95% formamide containing 20 mM EDTA and 0.02% methyl violet, and 5 µl of these mixtures were electrophoresed and visualized as described above. The resulting imager scan is shown in Fig. 50.

In Fig. 50, lane 1 contains the negative control; lanes 2-5 contain reactions performed using 100 mM KGlu; lanes 6-9 contain reactions performed using 250 mM KGlu. The reactions resolved in lanes 2 and 6 contained 1 fmole of target DNA; those in lanes 3 and 7 contained 100 amole of target; those in lanes 4 and 8 contained 10 amole of target and those in lanes 5 and 9 contained 1 amole of target. The results shown in Fig. 50 demonstrate that the detection limit using charge reversal to detect the production of specific cleavage products in an invasive cleavage reaction is at or below 1 attomole or approximately 6.02×10^5 target molecules. No detectable signal was observed in the control lane, which indicates that non-specific hydrolysis or other breakdown products do not migrate in the same direction as enzyme-specific cleavage products. The excitation and emission maxima for Cy3 are 554 and 568, respectively, while the FMBIO Imager Analyzer excites at 532 and detects at 585. Therefore, the limit of detection of specific cleavage products can be improved by the use of more closely matched excitation source and detection filters.

EXAMPLE 24

Devices And Methods For The Separation
And Detection Of Charged Reaction Products

5 This example is directed at methods and devices for isolating and concentrating
specific reaction products produced by enzymatic reactions conducted in solution whereby the
reactions generate charged products from either a charge neutral substrate or a substrate
bearing the opposite charge borne by the specific reaction product. The methods and devices
of this example allow isolation of, for example, the products generated by the invader-directed
10 cleavage assay of the present invention.

 The methods and devices of this example are based on the principle that when an
electric field is applied to a solution of charged molecules, the migration of the molecules
toward the electrode of the opposite charge occurs very rapidly. If a matrix or other
inhibitory material is introduced between the charged molecules and the electrode of opposite
15 charge such that this rapid migration is dramatically slowed, the first molecules to reach the
matrix will be nearly stopped, thus allowing the lagging molecules to catch up. In this way a
dispersed population of charged molecules in solution can be effectively concentrated into a
smaller volume. By tagging the molecules with a detectable moiety (*e.g.*, a fluorescent dye),
detection is facilitated by both the concentration and the localization of the analytes. This
20 example illustrates two embodiments of devices contemplated by the present invention; of
course, variations of these devices will be apparent to those skilled in the art and are within
the spirit and scope of the present invention.

 Fig. 51 depicts one embodiment of a device for concentrating the positively-charged
products generated using the methods of the present invention. As shown in Fig. 51, the
25 device comprises a reaction tube (10) which contains the reaction solution (11). One end of
each of two thin capillaries (or other tubes with a hollow core) (13A and 13B) are submerged
in the reaction solution (11). The capillaries (13A and 13B) may be suspended in the reaction
solution (11) such that they are not in contact with the reaction tube itself: one appropriate
method of suspending the capillaries is to hold them in place with clamps (not shown).
30 Alternatively, the capillaries may be suspended in the reaction solution (11) such that they are
in contact with the reaction tube itself. Suitable capillaries include glass capillary tubes
commonly available from scientific supply companies (*e.g.*, Fisher Scientific or VWR
Scientific) or from medical supply houses that carry materials for blood drawing and analysis.

Though the present invention is not limited to capillaries of any particular inner diameter, tubes with inner diameters of up to about 1/8 inch (approximately 3 mm) are particularly preferred for use with the present invention; for example Kimble No. 73811-99 tubes (VWR Scientific) have an inner diameter of 1.1 mm and are a suitable type of capillary tube.

5 Although the capillaries of the device are commonly composed of glass, any nonconductive tubular material, either rigid or flexible, that can contain either a conductive material or a trapping material is suitable for use in the present invention. One example of a suitable flexible tube is Tygon® clear plastic tubing (Part No. R3603; inner diameter = 1/16 inch; outer diameter = 1/8 inch).

10 As illustrated in Fig. 51, capillary 13A is connected to the positive electrode of a power supply (20) (e.g., a controllable power supply available through the laboratory suppliers listed above or through electronics supply houses like Radio Shack) and capillary 13B is connected to the negative electrode of the power supply (20). Capillary 13B is filled with a trapping material (14) capable of trapping the positively-charged reaction products by
15 allowing minimal migration of products that have entered the trapping material (14). Suitable trapping materials include, but are not limited to, high percentage (e.g., about 20%) acrylamide polymerized in a high salt buffer (0.5 M or higher sodium acetate or similar salt); such a high percentage polyacrylamide matrix dramatically slows the migration of the positively-charged reaction products. Alternatively, the trapping material may comprise a
20 solid, negatively-charged matrix, such as negatively-charged latex beads, that can bind the incoming positively-charged products. It should be noted that any amount of trapping material (14) capable of inhibiting any concentrating the positively-charged reaction products may be used. Thus, while the capillary 13B in Fig. 51 only contains trapping material in the lower, submerged portion of the tube, the trapping material (14) can be present in the entire
25 capillary (13B); similarly, less trapping material (14) could be present than that shown in Fig. 51 because the positively-charged reaction products generally accumulate within a very small portion of the bottom of the capillary (13B). The amount of trapping material need only be sufficient to make contact with the reaction solution (11) and have the capacity to collect the reaction products. When capillary 13B is not completely filled with the trapping
30 material, the remaining space is filled with any conductive material (15); suitable conductive materials are discussed below.

By comparison, the capillary (13A) connected to the positive electrode of the power supply 20 may be filled with any conductive material (15; indicated by the hatched lines in

Fig. 51). This may be the sample reaction buffer (e.g., 10 mM MOPS, pH 7.5 with 150 mM LiCl, 4 mM MnCl₂), a standard electrophoresis buffer (e.g., 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA), or the reaction solution (11) itself. The conductive material (15) is frequently a liquid, but a semi-solid material (e.g., a gel) or other suitable material might be easier to use and is within the scope of the present invention. Moreover, that trapping material used in the other capillary (i.e., capillary 13B) may also be used as the conductive material. Conversely, it should be noted that the same conductive material used in the capillary (13A) attached to the positive electrode may also be used in capillary 13B to fill the space above the region containing the trapping material (14) (see Fig. 51).

The top end of each of the capillaries (13A and 13B) is connected to the appropriate electrode of the power supply (20) by electrode wire (18) or other suitable material. Fine platinum wire (e.g., 0.1 to 0.4 mm, Aesar Johnson Matthey, Ward Hill, MA) is commonly used as conductive wire because it does not corrode under electrophoresis conditions. The electrode wire (18) can be attached to the capillaries (13A and 13B) by a nonconductive adhesive (not shown), such as the silicone adhesives that are commonly sold in hardware stores for sealing plumbing fixtures. If the capillaries are constructed of a flexible material, the electrode wire (18) can be secured with a small hose clamp or constricting wire (not shown) to compress the opening of the capillaries around the electrode wire. If the conducting material (15) is a gel, an electrode wire (18) can be embedded directly in the gel within the capillary.

The cleavage reaction is assembled in the reaction tube (10) and allowed to proceed therein as described in proceeding examples (e.g., Examples 22-23). Though not limited to any particular volume of reaction solution (11), a preferred volume is less than 10 ml and more preferably less than 0.1 ml. The volume need only be sufficient to permit contact with both capillaries. After the cleavage reaction is completed, an electric field is applied to the capillaries by turning on the power source (20). As a result, the positively-charged products generated in the course of the invader-directed cleavage reaction which employs an oligonucleotide, which when cleaved, generates a positively charged fragment (described in Ex. 23) but when uncleaved bears a net negative charge, migrate to the negative capillary, where their migration is slowed or stopped by the trapping material (14), and the negatively-charged uncut and thermally degraded probe molecules migrate toward the positive electrode. Through the use of this or a similar device, the positively-charged products of the invasive cleavage reaction are separated from the other material (i.e., uncut and thermally degraded

probe) and concentrated from a large volume. Concentration of the product in a small amount of trapping material (14) allows for simplicity of detection, with a much higher signal-to-noise ratio than possible with detection in the original reaction volume. Because the concentrated product is labelled with a detectable moiety like a fluorescent dye, a commercially-available fluorescent plate reader (not shown) can be used to ascertain the amount of product. Suitable plate readers include both top and bottom laser readers. Capillary 13B can be positioned with the reaction tube (10) at any desired position so as to accommodate use with either a top or a bottom plate reading device.

In the alternative embodiment of the present invention depicted in Fig. 52, the procedure described above is accomplished by utilizing only a single capillary (13B). The capillary (13B) contains the trapping material (14) described above and is connected to an electrode wire (18), which in turn is attached to the negative electrode of a power supply (20). The reaction tube (10) has an electrode (25) embedded into its surface such that one surface of the electrode is exposed to the interior of the reaction tube (10) and another surface is exposed to the exterior of the reaction tube. The surface of the electrode (25) on the exterior of the reaction tube is in contact with a conductive surface (26) connected to the positive electrode of the power supply (20) through an electrode wire (18). Variations of the arrangement depicted in Fig. 52 are also contemplated by the present invention. For example, the electrode (25) may be in contact with the reaction solution (11) through the use of a small hole in the reaction tube (10); furthermore, the electrode wire (18) can be directly attached to the electrode wire (18), thereby eliminating the conductive surface (26).

As indicated in Fig. 52, the electrode (25) is embedded in the bottom of a reaction tube (10) such that one or more reaction tubes may be set on the conductive surface (26). This conductive surface could serve as a negative electrode for multiple reaction tubes: such a surface with appropriate contacts could be applied through the use of metal foils (*e.g.*, copper or platinum, Aesar Johnson Matthey, Ward Hill, MA) in much the same way contacts are applied to circuit boards. Because such a surface contact would not be exposed to the reaction sample directly, less expensive metals, such as the copper could be used to make the electrical connections.

The above devices and methods are not limited to separation and concentration of positively charged oligonucleotides. As will be apparent to those skilled in the art, negatively charged reaction products may be separated from neutral or positively charged reactants using the above device and methods with the exception that capillary 13B is attached to the positive

electrode of the power supply (20) and capillary 13A or alternatively, electrode 25, is attached to the negative electrode of the power supply (20).

EXAMPLE 25

5 Primer-Directed And Primer Independent Cleavage
 Occur At The Same Site When The Primer Extends To
 The 3' Side Of A Mismatched "Bubble" In The Downstream Duplex

10 As discussed above in Example 1, the presence of a primer upstream of a bifurcated
 duplex can influence the site of cleavage, and the existence of a gap between the 3' end of
 the primer and the base of the duplex can cause a shift of the cleavage site up the unpaired 5'
 arm of the structure (see also Lyamichev *et al.*, *supra* and U.S. Patent No. 5,422,253). The
 resulting non-invasive shift of the cleavage site in response to a primer is demonstrated in
15 Figs. 8, 9 and 10, in which the primer used left a 4-nucleotide gap (relative to the base of the
 duplex). In Figs. 8-10, all of the "primer-directed" cleavage reactions yielded a 21 nucleotide
 product, while the primer-independent cleavage reactions yielded a 25 nucleotide product.
 The site of cleavage obtained when the primer was extended to the base of the duplex,
 leaving no gap was examined. The results are shown in Fig. 53 (Fig. 53 is a reproduction of
 Fig. 2C in Lyamichev *et al.* These data were derived from the cleavage of the structure
20 shown in Fig. 5, as described in Example 1. Unless otherwise specified, the cleavage
 reactions comprised 0.01 pmoles of heat-denatured, end-labeled hairpin DNA (with the
 unlabeled complementary strand also present), 1 pmole primer [complementary to the 3' arm
 shown in Fig. 5 and having the sequence: 5'-GAATTCGATTTAGGTGACAC
 TATAGAATACA (SEQ ID NO:53)] and 0.5 units of DNAP_{Taq} (estimated to be 0.026
25 pmoles) in a total volume of 10 μ l of 10 mM Tris-Cl, pH 8.5, and 1.5 mM MgCl₂ and 50 mM
 KCl. The primer was omitted from the reaction shown in the first lane of Fig. 53 and
 included in lane 2. These reactions were incubated at 55°C for 10 minutes. Reactions were
 initiated at the final reaction temperature by the addition of either the MgCl₂ or enzyme.
 Reactions were stopped at their incubation temperatures by the addition of 8 μ l of 95%
30 formamide with 20 mM EDTA and 0.05% marker dyes.

 Fig. 53 is an autoradiogram that indicates the effects on the site of cleavage of a
 bifurcated duplex structure in the presence of a primer that extends to the base of the hairpin
 duplex. The size of the released cleavage product is shown to the left (*i.e.*, 25 nucleotides).

A dideoxynucleotide sequencing ladder of the cleavage substrate is shown on the right as a marker (lanes 3-6).

These data show that the presence of a primer that is adjacent to a downstream duplex (lane 2) produces cleavage at the same site as seen in reactions performed in the absence of the primer (lane 1). (See Figs. 8A and B, 9B and 10A for additional comparisons). When the 3' terminal nucleotides of the upstream oligonucleotide can base pair to the template strand but are not homologous to the displaced strand in the region immediately upstream of the cleavage site (*i.e.* when the upstream oligonucleotide is opening up a "bubble" in the duplex), the site to which cleavage is apparently shifted is not wholly dependent on the presence of an upstream oligonucleotide.

As discussed above in the Background section and in Table 1, the requirement that two independent sequences be recognized in an assay provides a highly desirable level of specificity. In the invasive cleavage reactions of the present invention, the invader and probe oligonucleotides must hybridize to the target nucleic acid with the correct orientation and spacing to enable the production of the correct cleavage product. When the distinctive pattern of cleavage is not dependent on the successful alignment of both oligonucleotides in the detection system these advantages of independent recognition are lost.

EXAMPLE 26

Invasive Cleavage And Primer-Directed Cleavage When There Is Only Partial Homology In The "X" Overlap Region

While not limiting the present invention to any particular mechanism, invasive cleavage occurs when the site of cleavage is shifted to a site within the duplex formed between the probe and the target nucleic acid in a manner that is dependent on the presence of an upstream oligonucleotide which shares a region of overlap with the downstream probe oligonucleotide. In some instances, the 5' region of the downstream oligonucleotide may not be completely complementary to the target nucleic acid. In these instances, cleavage of the probe may occur at an internal site within the probe even in the absence of an upstream oligonucleotide (in contrast to the base-by-base nibbling seen when a fully paired probe is used without an invader). Invasive cleavage is characterized by an apparent shifting of cleavage to a site within a downstream duplex that is dependent on the presence of the invader oligonucleotide.

A comparison between invasive cleavage and primer-directed cleavage may be illustrated by comparing the expected cleavage sites of a set of probe oligonucleotides having decreasing degrees of complementarity to the target strand in the 5' region of the probe (*i.e.*, the region that overlaps with the invader). A simple test, similar to that performed on the hairpin substrate above (Ex. 25), can be performed to compare invasive cleavage with the non- invasive primer-directed cleavage described above. Such a set of test oligonucleotides is diagrammed in Fig. 54. The structures shown in Fig. 54 are grouped in pairs, labeled "a", "b", "c", and "d". Each pair has the same probe sequence annealed to the target strand (SEQ ID NO:54), but the top structure of each pair is drawn without an upstream oligonucleotide, while the bottom structure includes this oligonucleotide (SEQ ID NO:55). The sequences of the probes shown in Figs. 54a-54d are listed in SEQ ID NOS:32, 56, 57 and 58, respectively. Probable sites of cleavage are indicated by the black arrowheads. (It is noted that the precise site of cleavage on each of these structures may vary depending on the choice of cleavage agent and other experimental variables. These particular sites are provided for illustrative purposes only.)

To conduct this test, the site of cleavage of each probe is determined both in the presence and the absence of the upstream oligonucleotide, in reaction conditions such as those described in Example 18. The products of each pair of reactions are then be compared to determine whether the fragment released from the 5' end of the probe increases in size when the upstream oligonucleotide is included in the reaction.

The arrangement shown in Fig. 54a, in which the probe molecule is completely complementary to the target strand, is similar to that shown in Fig. 28. Treatment of the top structure with the 5' nuclease of a DNA polymerase would cause exonucleolytic nibbling of the probe (*i.e.*, in the absence of the upstream oligonucleotide). In contrast, inclusion of an invader oligonucleotide would cause a distinctive cleavage shift similar, to those observed in Fig. 29.

The arrangements shown in Figs. 54b and 54c have some amount of unpaired sequence at the 5' terminus of the probe (3 and 5 bases, respectively). These small 5' arms are suitable cleavage substrate for the 5' nucleases and would be cleaved within 2 nucleotide's of the junction between the single stranded region and the duplex. In these arrangements, the 3' end of the upstream oligonucleotide shares identity with a portion of the 5' region of the probe which is complementary to the target sequence (that is the 3' end of the invader has to compete for binding to the target with a portion of the 5' end of the probe). Therefore, when

the upstream oligonucleotide is included it is thought to mediate a shift in the site of cleavage into the downstream duplex (although the present invention is not limited to any particular mechanism of action), and this would, therefore, constitute invasive cleavage. If the extreme 5' nucleotides of the unpaired region of the probe were able to hybridize to the target strand, the cleavage site in the absence of the invader might change but the addition of the invader oligonucleotide would still shift the cleavage site to the proper position.

Finally, in the arrangement shown in Fig. 54d, the probe and upstream oligonucleotides share no significant regions of homology, and the presence of the upstream oligonucleotide would not compete for binding to the target with the probe. Cleavage of the structures shown in Fig. 54d would occur at the same site with or without the upstream oligonucleotide, and is thus would not constitute invasive cleavage.

By examining any upstream oligonucleotide/probe pair in this way, it can easily be determined whether the resulting cleavage is invasive or merely primer-directed. Such analysis is particularly useful when the probe is not fully complementary to the target nucleic acid, so that the expected result may not be obvious by simple inspection of the sequences.

EXAMPLE 27

Modified Cleavase® Enzymes

In order to develop nucleases having useful activities for the cleavage of nucleic acids the following modified nucleases were produced.

a) Cleavase® BN/thrombin Nuclease

i) Cloning and Expression of Cleavase® BN/thrombin Nuclease

Site directed mutagenesis was used to introduce a protein sequence recognized by the protease thrombin into the region of the Cleavase® BN nuclease which is thought to form the helical arch of the protein through which the single-stranded DNA that is cleaved must presumably pass. Mutagenesis was carried out using the Transformer™ mutagenesis kit (Clontech, Palo Alto, CA) according to manufacturer's protocol using the mutagenic oligonucleotide 5'-GGGAAAGTCCTCGCAGCCGCGCGGGACGAGCGTGGGGGCCCCG (SEQ ID NO:59). After mutagenesis, the DNA was sequenced to verify the insertion of the thrombin cleavage site. The DNA sequence encoding the Cleavase® BN/thrombin nuclease is

provided in SEQ ID NO:60; the amino acid sequence of Cleavase® BN/thrombin nuclease is provided in SEQ ID NO:61.

A large scale preparation of the thrombin mutant (*i.e.*, Cleavase® BN/thrombin) was done using *E. coli* cells overexpressing the Cleavase® BN/thrombin nuclease as described in Example 28.

ii) **Thrombin Cleavage of Cleavase® BN/thrombin**

Six point four (6.4) mg of the purified Cleavase® BN/thrombin nuclease was digested with 0.4 U of thrombin (Novagen) for 4 hours at 23°C or 37°C. Complete digestion was verified by electrophoresis on a 15% SDS polyacrylamide gel followed by staining with Coomassie Brilliant Blue R. Wild-type Cleavase® BN nuclease was also digested with thrombin as a control. The resulting gel is shown in Fig. 61.

In Fig. 61, lane 1 contains molecular weight markers (Low-Range Protein Molecular Weight Markers: Promega), lane 2 contains undigested Cleavase® BN/thrombin nuclease, lanes 3 and 4 contain Cleavase® BN/thrombin nuclease digested with thrombin at 23°C for 2 and 4 hours, respectively, and lanes 5 and 6 contain Cleavase® BN/thrombin nuclease digested with thrombin at 37°C for 2 and 4 hours, respectively. These results show that the Cleavase® BN/thrombin nuclease has an apparent molecular weight of 36.5 kilodaltons and demonstrate that Cleavase® BN/thrombin nuclease is efficiently cleaved by thrombin. In addition, the thrombin cleavage products have approximate molecular weights of 27 kilodaltons and 9 kilodaltons, the size expected based upon the position of the inserted thrombin site in the Cleavase® BN/thrombin nuclease.

To determine the level of hairpin cleavage activity in digested and undigested Cleavase® BN/thrombin nuclease, dilutions were made and used to cleave a test hairpin containing a 5' fluorescein label. Varying amounts of digested and undigested Cleavase® BN/thrombin nuclease were incubated with 5 µM oligonucleotide S-60 hairpin (SEQ ID NO:29; see Fig. 26) in 10 mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40, and 1 mM MnCl₂ for 5 minutes at 60°C. The digested mixture was electrophoresed on a 20% acrylamide gel and visualized on a Hitachi FMBIO 100 fluorimager. The resulting image is shown in Fig. 62.

In Fig. 62, lane 1 contains the no enzyme control, lane 2 contains reaction products produced using 0.01 ng of Cleavase® BN nuclease, lanes 3, 4, and 5 contain reaction products produced using 0.01 ng, 0.04 ng, and 4 ng of undigested Cleavase® BN/thrombin nuclease, respectively, and lanes 6, 7, and 8 contain reaction products produced using 0.01 ng,

0.04 ng, and 4 ng of thrombin-digested Cleavase® BN/thrombin nuclease, respectively. The results shown in Fig. 62 demonstrated that the insertion of the thrombin cleavage site reduced cleavage activity about 200-fold (relative to the activity of Cleavase® BN nuclease), but that digestion with thrombin did not reduce the activity significantly.

5 M13 single-stranded DNA was used as a substrate for cleavage by Cleavase® BN nuclease and digested and undigested Cleavase® BN/thrombin nuclease. Seventy nanograms of single-stranded M13 DNA (New England Biolabs, Beverly, MA) was incubated in 10 mM MOPS, pH 7.5, 0.05% Tween-20, 0.05% NP-40, 1 mM MgCl₂ or 1 mM MnCl₂, with 8 ng of Cleavase® BN nuclease, undigested Cleavase® BN/thrombin nuclease, or digested Cleavase®
10 BN/thrombin nuclease for 10 minutes at 50°C. Reaction mixtures were electrophoresed on a 0.8% agarose gel and then stained with a solution containing 0.5 µg/ml ethidium bromide (EtBr) to visualize DNA bands. A negative image of the EtBr-stained gel is shown in Fig. 63.

In Fig. 63, lane 1 contains the no enzyme control, lane 2 contains reaction products
15 produced using Cleavase® BN nuclease and 1 mM MgCl₂, lane 3 contains reaction products produced using Cleavase® BN nuclease and 1 mM MnCl₂, lane 4 contains reaction products produced using undigested Cleavase® BN/thrombin nuclease and 1 mM MgCl₂, lane 5 contains reaction products produced using undigested Cleavase® BN/thrombin nuclease and 1 mM MnCl₂, lane 6 contains reaction products produced using thrombin-digested Cleavase®
20 BN/thrombin nuclease and 1 mM MgCl₂, and lane 7 contains reaction products produced using thrombin-digested Cleavase® BN/thrombin nuclease and 1 mM MnCl₂. The results shown in Fig. 63 demonstrated that the Cleavase® BN/thrombin nuclease had an enhanced ability to cleave circular DNA (and thus a reduced requirement for the presence of a free 5' end) as compared to the Cleavase® BN nuclease.

25 It can be seen from these data that the helical arch of these proteins can be opened without destroying the enzyme or its ability to specifically recognize cleavage structures. The Cleavase® BN/thrombin mutant has an increased ability to cleave without reference to a 5' end, as discussed above. The ability to cleave such structures will allow the cleavage of long molecules, such as genomic DNA that, while often not circular, may present many desirable
30 cleavage sites that are at a far removed from any available 5' end. Cleavage structures may be made at such sites either by folding of the strands (*i.e.*, CFLP® cleavage) or by the introduction of structure-forming oligonucleotides (U.S. Patent No. 5,422,253). 5' ends of nucleic acids can also be made unavailable because of binding of a substance too large to

thread through the helical arch. Such binding moieties may include proteins such as streptavidin or antibodies, or solid supports such as beads or the walls of a reaction vessel. A cleavage enzyme with an opening in the loop of the helical arch will be able to cleave DNAs that are configured in this way, extending the number of ways in which reactions using such enzymes can be formatted.

b) Cleavase® DN Nuclease

i) Construction and Expression of Cleavase® DN Nuclease

A polymerization deficient mutant of *Taq* DNA polymerase, termed Cleavase® DN nuclease, was constructed. Cleavase® DN nuclease contains an asparagine residue in place of the wild-type aspartic acid residue at position 785 (D785N).

DNA encoding the Cleavase® DN nuclease was constructed from the gene encoding for Cleavase® A/G (mut*Taq*, Ex. 2) in two rounds of site-directed mutagenesis. First, the G at position 1397 and the G at position 2264 of the Cleavase® A/G gene (SEQ ID NO:21) were changed to A at each position to recreate a wild-type DNAPTaq gene. As a second round of mutagenesis, the wild type DNAPTaq gene was converted to the Cleavase® DN gene by changing the G at position 2356 to A. These manipulations were performed as follows.

DNA encoding the Cleavase® A/G nuclease was recloned from pTTQ18 plasmid (Ex. 2) into the pTrc99A plasmid (Pharmacia) in a two step procedure.

First, the pTrc99A vector was modified by removing the G at position 270 of the pTrc99A map, creating the pTrc99G cloning vector. To this end, pTrc99A plasmid DNA was cut with *Nco*I and the recessive 3' ends were filled-in using the Klenow fragment of *E.coli* polymerase I in the presence of all four dNTPs at 37°C for 15 min. After inactivation of the Klenow fragment by incubation at 65°C for 10 min, the plasmid DNA was cut with *Eco*RI, the ends were again filled-in using the Klenow fragment in the presence of all four dNTPs at 37°C for 15 min. The Klenow fragment was then inactivated by incubation at 65°C for 10 min. The plasmid DNA was ethanol precipitated, recircularized by ligation, and used to transform *E.coli* JM109 cells (Promega). Plasmid DNA was isolated from single colonies and deletion of the G at position 270 of the pTrc99A map was confirmed by DNA sequencing.

As a second step, DNA encoding the Cleavase® A/G nuclease was removed from the pTTQ18 plasmid using *Eco*RI and *Sa*I and the DNA fragment carrying the Cleavase® A/G nuclease gene was separated on a 1% agarose gel and isolated with Geneclean II Kit (Bio

101, Vista, CA). The purified fragment was ligated into the pTrc99G vector which had been cut with *EcoRI* and *SaII*. The ligation mixture was used to transform competent *E. coli* JM109 cells (Promega). Plasmid DNA was isolated from single colonies and insertion of the Cleavase® A/G nuclease gene was confirmed by restriction analysis using *EcoRI* and *SaII*.

5 Plasmid DNA pTrcAG carrying the Cleavase® A/G nuclease gene cloned into the pTrc99A vector was purified from 200 ml of JM109 overnight culture using QIAGEN Plasmid Maxi kit (QIAGEN, Chatsworth, CA) according to manufacturer's protocol. pTrcAG plasmid DNA was mutagenized using two mutagenic primers, E465 (SEQ ID NO:62) (Integrated DNA Technologies, Iowa) and R754Q (SEQ ID NO:63) (Integrated DNA
10 Technologies), and the selection primer Trans Oligo AlwNI/SpeI (Clontech, Palo Alto, CA, catalog #6488-1) according to Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech) to produce a restored wild-type DNAPTaq gene (pTrcWT).

pTrcWT plasmid DNA carrying the wild-type DNAPTaq gene cloned into the pTrc99A vector was purified from 200 ml of JM109 overnight culture using QIAGEN
15 Plasmid Maxi kit (QIAGEN, Chatsworth, CA) according to manufacturer's protocol. pTrcWT was then mutagenized using the mutagenic primer D785N (SEQ ID NO:64) (Integrated DNA Technologies) and the selection primer Switch Oligo SpeI/AlwNI (Clontech, catalog #6373-1) according to Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech) to create a plasmid containing DNA encoding the Cleavase® DN nuclease. The DNA sequence encoding
20 the Cleavase® DN nuclease is provided in SEQ ID NO:65; the amino acid sequence of Cleavase® DN nuclease is provided in SEQ ID NO:66.

A large scale preparation of the Cleavase® DN nuclease was done using *E. coli* cells overexpressing the Cleavase® DN nuclease as described in Example 28.

25 **c) Cleavase® DA Nuclease and Cleavase® DV Nuclease**

Two polymerization deficient mutants of *Taq* DNA polymerase, termed Cleavase® DA nuclease and Cleavase® DV nuclease, were constructed. The Cleavase® DA nuclease contains an alanine residue in place of the wild-type aspartic acid residue at position 610 (D785A). The Cleavase® DV nuclease contains a valine residue in place of the wild-type
30 aspartic acid residue at position 610 (D610V).

i) **Construction and Expression of the Cleavase® DA and Cleavase® DV Nucleases**

To construct vectors encoding the Cleavase® DA and DV nucleases, the Cleavase® A/G nuclease gene contained within pTrcAG was mutagenized with two mutagenic primers, R754Q (SEQ ID NO:63) and D610AV (SEQ ID NO:67) and the selection primer Trans Oligo AlwNI/SpeI (Clontech, catalog #6488-1) according to the Transformer™ Site-Directed Mutagenesis Kit protocol (Clontech,) to create a plasmid containing DNA encoding the Cleavase® DA nuclease or Cleavase® DV nuclease. The D610AV oligonucleotide was synthesized to have a purine, A or G, at position 10 from the 5' end of the oligonucleotide. Following mutagenesis, plasmid DNA was isolated from single colonies and the type of mutation present, DA or DV, was determined by DNA sequencing. The DNA sequence encoding the Cleavase® DA nuclease is provided in SEQ ID NO:68; the amino acid sequence of Cleavase® DA nuclease is provided in SEQ ID NO:69. The DNA sequence encoding the Cleavase® DV nuclease is provided in SEQ ID NO:70; the amino acid sequence of Cleavase® DV nuclease is provided in SEQ ID NO:71.

Large scale preparations of the Cleavase® DA and Cleavase® DV nucleases was done using *E. coli* cells overexpressing the Cleavase® DA nuclease or the Cleavase® DV nuclease as described in Example 28.

EXAMPLE 28

Cloning And Expression of Thermostable FEN-1 Endonucleases

Sequences encoding thermostable FEN-1 proteins derived from three Archaeobacterial species were cloned and overexpressed in *E. coli*. This example involved a) cloning and expression of a FEN-1 endonuclease from *Methanococcus jannaschii*; b) cloning and expression of a FEN-1 endonuclease from *Pyrococcus furiosus*; c) cloning and expression of a FEN-1 endonuclease from *Pyrococcus woesei*; d) large scale preparation of recombinant thermostable FEN-1 proteins; and e) activity assays using FEN-1 endonucleases.

a) **Cloning and Expression Of A FEN-1 Endonuclease From *Methanococcus jannaschii***

DNA encoding the FEN-1 endonuclease from *Methanococcus jannaschii* (*M. jannaschii*) was isolated from *M. jannaschii* cells and inserted into a plasmid under the

transcriptional control of an inducible promoter as follows. Genomic DNA was prepared from 1 vial of live *M. jannaschii* bacteria (DSMZ, Deutsche Sammlung von Mikroorganismen und Zellkulturen, Braunschweig, Germany # 2661) with the DNA XTRAX kit (Gull Laboratories, Salt Lake City, UT) according to the manufacturer's protocol. The final DNA pellet was resuspended in 100 µl of TE (10 mM Tris HCl, pH 8.0, 1 mM EDTA). One microliter of the DNA solution was employed in a PCR using the Advantage™ cDNA PCR kit (Clontech); the PCR was conducted according to manufacturer's recommendations. The 5'-end primer (SEQ ID NO:72) is complementary to the 5' end of the *Mja* FEN-1 open reading frame with a one base substitution to create an *Nco*I restriction site [a fragment of the *M. jannaschii* genome which contains the gene encoding *M. jannaschii* (*Mja*) FEN-1 is available from GenBank as accession # U67585]. The 3'-end primer (SEQ ID NO:73) is complementary to a sequence about 15 base pairs downstream from the 3' end of the *Mja* FEN-1 open reading frame with 2 base substitutions to create a *Sal*I restriction enzyme site. The sequences of the 5'-end and 3'-end primers are: 5'-GGGATACCA TGGGAGTGCAGTTTGG-3' (SEQ ID NO:72) and 5'-GGTAAATTTTCTCGTCCA CATCCCAC-3' (SEQ ID NO:73), respectively. The PCR reaction resulted in the amplification (*i.e.*, production) of a single major band about 1 kilobase in length. The open reading frame (ORF) encoding the *Mja* FEN-1 endonuclease is provided in SEQ ID NO:74; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:75.

Following the PCR amplification, the entire reaction was electrophoresed on a 1.0% agarose gel and the major band was excised from the gel and purified using the GeneClean II kit (Bio101, Vista, CA) according to manufacturer's instructions. Approximately 1 µg of the gel-purified *Mja* FEN-1 PCR product was digested with *Nco*I and *Sal*I. After digestion, the DNA was purified using the GeneClean II kit according to manufacturer's instructions. One microgram of the pTrc99a vector (Pharmacia, Piscataway, NJ) was digested with *Nco*I and *Sal*I in preparation for ligation with the digested PCR product. One hundred nanograms of digested pTrc99a vector and 250 ng of digested *Mja* FEN-1 PCR product were combined and ligated to create pTrc99-MJFEN1. pTrc99-MJFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

b) **Cloning and Expression Of A FEN-1 Endonuclease From *Pyrococcus furiosus***

DNA encoding the *Pyrococcus furiosus* (*P. furiosus*) FEN-1 endonuclease was obtained by PCR amplification using a plasmid containing DNA encoding the *P. furiosus* (*Pfu*) FEN-1 endonuclease (obtained from Dr. Frank Robb, Center of Marine Biotechnology, Baltimore, MD). DNA sequences encoding a portion of the *Pfu* FEN-1 endonuclease can be obtained from GenBank as accession Nos. AA113505 and W36094. The amplified *Pfu* FEN-1 gene was inserted into the pTrc99a expression vector (Pharmacia) to place the *Pfu* FEN-1 gene under the transcriptional control of the inducible *trc* promoter. The PCR amplification was conducted as follows. One hundred microliter reactions contained 50 mM Tris HCl, pH 9.0, 20 mM (NH₄)₂SO₄, 2 mM MgCl₂, 50 μM dNTPs, 50 pmole each primer, 1 U *Tfl* polymerase (Epicentre Technologies, Madison, WI) and 1 ng of FEN-1 gene-containing plasmid DNA. The 5'-end primer (SEQ ID NO:76) is complementary to the 5' end of the *Pfu* FEN-1 open reading frame but with two substitutions to create an *Nco*I site and the 3'-end primer (SEQ ID NO:77) is complementary to a region located about 30 base pairs downstream of the FEN-1 open reading frame with two substitutions to create a *Pst*I site. The sequences of the 5'-end and 3'-end primers are: 5'-GAGGTGATACCATG GGTGTCC-3' (SEQ ID NO:76) and 5'-GAAACTCTGCAGCGCGTCAG-3' (SEQ ID NO:77), respectively. The PCR reaction resulted in the amplification of a single major band about 1 kilobase in length. The open reading frame (ORF) encoding the *Pfu* FEN-1 endonuclease is provided in SEQ ID NO:78; the amino acid sequence encoded by this ORF is provided in SEQ ID NO:79.

Following the PCR amplification, the entire reaction was electrophoresed on a 1.0% agarose gel and the major band was excised from the gel and purified using the GeneClean II kit (Bio101) according to manufacturer's instructions. Approximately 1 μg of gel purified *Pfu* FEN-1 PCR product was digested with *Nco*I and *Pst*I. After digestion, the DNA was purified using the GeneClean II kit according to manufacturer's instructions. One microgram of the pTrc99a vector was digested with *Nco*I and *Pst*I prior to ligation with the digested PCR product. One hundred nanograms of digested pTrc99a and 250 ng of digested *Pfu* FEN-1 PCR product were combined and ligated to create pTrc99-PFFEN1. pTrc99-PFFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

c) Cloning and Expression Of A FEN-1 Endonuclease From *Pyrococcus woesei*

For the cloning of DNA encoding the *Pyrococcus woesei* (*Pwo*) FEN-1 endonuclease. DNA was prepared from lyophilized *P. woesei* bacteria (DSMZ # 3773) as described [Zwickl
5 *et al.* (1990) J. Bact. 172:4329] with several changes. Briefly, one vial of *P. woesei* bacteria was rehydrated and resuspended in 0.5 ml of LB (Luria broth). The cells were centrifuged at 14,000 x g for 1 min and the cell pellet was resuspended in 0.45 ml of TE. Fifty microliters of 10% SDS was added and the mixture was incubated at RT for 5 min. The cell lysate was then extracted three times with 1:1 phenol:chloroform and three times with chloroform. Five
10 hundred microliters of isopropanol was added to the extracted lysate and the DNA was pelleted by centrifugation at 14,000 x g for 10 min. The DNA pellet was washed in 0.5 ml of 70% ethanol and the DNA was pelleted again by centrifugation at 14,000 x g for 5 min. The DNA pellet was dried and resuspended in 100 µl of TE and used for PCR reactions without further purification.

15 To generate a *P. woesei* FEN-1 gene fragment for cloning into an expression vector, low stringency PCR was attempted with primers complementary to the ends of the *P. furiosus* FEN-1 gene open reading frame. The sequences of the 5'-end and 3'-end primers are 5'-GATACCATGGGTGTCCCAATTGGTG-3' (SEQ ID NO:80) and 5'-TCGACGTCGACTTATCTCTTGAACCAACTTTCAAGGG-3' (SEQ ID NO:81),
20 respectively. The high level of sequence similarity of protein homologs (*i.e.*, proteins other than FEN-1 proteins) from *P. furiosus* and *P. woesei* suggested that there was a high probability that the *P. woesei* FEN-1 gene could be amplified using primers containing sequences complementary to the *P. furiosus* FEN-1 gene. However, this approach was unsuccessful under several different PCR conditions.

25 The DNA sequence of FEN-1 genes from *P. furiosus* and *M. jannaschii* were aligned and blocks of sequence identity between the two genes were identified. These blocks were used to design internal primers (*i.e.*, complementary to sequences located internal to the 5' and 3' ends of the ORF) for the FEN-1 gene that are complementary to the *P. furiosus* FEN-1 gene in those conserved regions. The sequences of the 5'- and 3'-internal primers are
30 5'-AGCGAGGGAGAGGCCCAAGC-3' (SEQ ID NO:82) and 5'-GCCTATGCCCTTATTCCTCC-3' (SEQ ID NO:83), respectively. A PCR employing these internal primers was conducted using the Advantage™ PCR kit and resulted in production of a major band of ~300 bp.

Since the PCR with the internal primers was successful, reactions were attempted which contained mixtures of the internal (SEQ ID NOS:82 and 83) and external (SEQ ID NOS:80 and 81) primers. A reaction containing the 5'-end external primer (SEQ ID NO:80) and 3'-end internal primer (SEQ ID NO:83) resulted in the production of a 600 bp band and a
5 reaction containing the 5'-end internal primer (SEQ ID NO:82) and 3'-end external primer (SEQ ID NO:81) resulted in the production of a 750 bp band. These overlapping DNA fragments were gel-purified and combined with the external primers (SEQ ID NOS:80 and 81) in a PCR reaction. This reaction generated a 1 kb DNA fragment containing the entire *Pwo* FEN-1 gene open reading frame. The resulting PCR product was gel-purified, digested,
10 and ligated exactly as described above for the *Mja* FEN-1 gene PCR product. The resulting plasmid was termed pTrc99-PWFEN1. pTrc99-PWFEN1 was used to transform competent *E. coli* JM109 cells (Promega) using standard techniques.

d) Large Scale Preparation of Recombinant Thermostable FEN-1 Proteins

15 The *Mja*, *Pwo* and *Pfu* FEN-1 proteins were purified by the following technique which is derived from a *Taq* DNA polymerase preparation protocol [Engelke *et al.* (1990) Anal. Biochem. 191:396] as follows. *E. coli* cells (strain JM109) containing either pTrc99-PFFEN1, pTrc99-PWFEN1, or pTrc99-MJFEN1 were inoculated into 3 ml of LB (Luria Broth) containing 100 µg/ml ampicillin and grown for 16 hrs at 37°C. The entire overnight culture
20 was inoculated into 200 ml or 350 ml of LB containing 100 µg/ml ampicillin and grown at 37°C with vigorous shaking to an A_{600} of 0.8. IPTG (1 M stock solution) was added to a final concentration of 1 mM and growth was continued for 16 hrs at 37°C.

The induced cells were pelleted and the cell pellet was weighed. An equal volume of 2X DG buffer (100 mM Tris-HCl, pH 7.6, 0.1 mM EDTA) was added and the pellet was
25 resuspended by agitation. Fifty mg/ml lysozyme (Sigma, St. Louis, MO) was added to 1 mg/ml final concentration and the cells were incubated at room temperature for 15 min. Deoxycholic acid (10% solution) was added dropwise to a final concentration of 0.2 % while vortexing. One volume of H₂O and 1 volume of 2X DG buffer was added and the resulting mixture was sonicated for 2 minutes on ice to reduce the viscosity of the mixture. After
30 sonication, 3 M (NH₄)₂SO₄ was added to a final concentration of 0.2 M and the lysate was centrifuged at 14000 x g for 20 min at 4°C. The supernatant was removed and incubated at 70°C for 60 min at which time 10% polyethylimine (PEI) was added to 0.25%. After incubation on ice for 30 min., the mixture was centrifuged at 14,000 x g for 20 min at 4°C.

At this point, the supernatant was removed and the FEN-1 proteins was precipitated by the addition of $(\text{NH}_4)_2\text{SO}_4$ as follows.

For the *Pwo* and the *Pfu* FEN-1 preparations, the FEN-1 protein was precipitated by the addition of 2 volumes of 3 M $(\text{NH}_4)_2\text{SO}_4$. The mixture was incubated overnight at room temperature for 16 hrs and the protein was centrifuged at 14,000 x g for 20 min at 4°C. The protein pellet was resuspended in 0.5 ml of Q buffer (50 mM Tris-HCl, pH 8.0, 0.1 mM EDTA, 0.1% Tween 20). For the *Mja* FEN-1 preparation, solid $(\text{NH}_4)_2\text{SO}_4$ was added to a final concentration of 3 M (~75% saturated), the mixture was incubated on ice for 30 min, and the protein was spun down and resuspended as described above.

The resuspended protein preparations were quantitated by determination of the A_{279} and aliquots containing 2-4 µg of total protein were electrophoresed on a 10 % SDS polyacrylamide gel (29:1 acrylamide: bis-acrylamide) in standard Laemmli buffer [Laemmli (1970) Nature 227:680] and stained with Coomassie Brilliant Blue R; the results are shown in Fig. 64.

In Fig. 64, lane 1 contains molecular weight markers (Mid-Range Protein Molecular Weight Markers; Promega); the size of the marker proteins is indicated to the left of the gel. Lane 2 contains purified Cleavase® BN nuclease; lanes 3-5 contain extracts prepared from *E. coli* expressing the *Pfu*, *Pwo* and *Mja* FEN-1 nucleases, respectively. The calculated (*i.e.*, using a translation of the DNA sequence encoding the nuclease) molecular weight of the *Pfu* FEN-1 nuclease is 38,714 daltons and the calculated molecular weight for the *Mja* FEN-1 nuclease is 37,503 Daltons. The *Pwo* and *Pfu* FEN-1 proteins co-migrated on the SDS-PAGE gel and therefore, the molecular weight of the *Pwo* FEN-1 nuclease was estimated to be 38.7 kDa.

e) Activity Assays Using FEN-1 Endonucleases

i) Mixed Hairpin Assay

The Cleavase® BN nuclease has an approximately 60-fold greater affinity for a 12 base pair stem-loop structure than an 8 base pair stem-loop DNA structure. As a test for activity differences between the Cleavase® BN nuclease and the FEN-1 nucleases, a mixture of oligonucleotides having either a 8 or a 12 bp stem-loop (see Fig. 60 which depicts the S-33 and 11-8-0 oligonucleotides) was incubated with an extract prepared from *E. coli* cells overexpressing the *Mja* FEN-1 nuclease (prepared as described above). Reactions contained 0.05 µM of oligonucleotides S-33 (SEQ ID NO:84) and 11-8-0 (SEQ ID NO:85) (both

oligonucleotides contained 5'-fluorescein labels). 10 mM MOPS, pH 7.5, 0.05% Tween-20, 0.05% NP-40, 1 mM MnCl₂. Reactions were heated to 90°C for 10 seconds, cooled to 55°C, then 1 µl of crude extract (*Mja* FEN-1) or purified enzyme (Cleavase® BN nuclease) was added and the mixtures were incubated at 55°C for 10 minutes; a no enzyme control was also run. The reactions were stopped by the addition of formamide/EDTA, the samples were electrophoresed on a denaturing 20% acrylamide gel and visualized on a Hitachi FMBIO 100 fluoroiager. The resulting image is shown in Fig. 65.

In Fig. 65, lane 1 contains the reaction products generated by the Cleavase® BN nuclease, lane 2 contains the reaction products from the no enzyme control reaction and lane 3 contains the reaction products generated by the *Mja* FEN-1 nuclease. The data shown in Fig. 76 demonstrates that the Cleavase® BN nuclease strongly prefers the S33 structure (12 bp stem-loop) while the *Mja* FEN-1 nuclease cleaves structures having either an 8 or a 12 bp stem-loop with approximately the same efficiency. This shows that the *Mja* FEN-1 nuclease has a different substrate specificity than the Cleavase® BN nuclease, a useful feature for Invader™ assays or CFLP® analysis as discussed in the Description of the Invention.

EXAMPLE 29

Terminal Deoxynucleotidyl Transferase Selectively Extends The Products Of Invader™-Directed Cleavage

20

The majority of thermal degradation products of DNA probes will have a phosphate at the 3'-end. To investigate if the template-independent DNA polymerase, terminal deoxynucleotide transferase (TdT) can tail or polymerize the aforementioned 3'-end phosphates (*i.e.*, add nucleotide triphosphates to the 3' end) the following experiment was performed.

25

To create a sample containing a large percentage of thermal degradation products, the 5' fluorescein-labelled oligonucleotide 34-078-01 (SEQ ID NO:86) (200 pmole) was incubated in 100 µl 10 mM NaCO₃ (pH 10.6), 50 mM NaCl at 95°C for 13 hours. To prevent evaporation, the reaction mixture was overlaid with 60 µl ChillOut™14 liquid wax. The reaction mixture was then divided into two equal aliquots (A and B). Aliquot A was mixed with one-tenth volume 3M NaOAc followed by three volumes ethanol and stored at -20°C. Aliquot B was dephosphorylated by the addition of 0.5 µl of 1M MgCl₂ and 1 µl of 1unit/µl Calf Intestine Alkaline Phosphatase (CIAP) (Promega), with incubation at 37°C for

30

30 minutes. An equal volume of phenol:chloroform: isomayl alcohol (24:24:1) was added to the sample followed by vortexing for one minute and then centrifugation 5 minutes at maximum speed in a microcentrifuge to separate the phases. The aqueous phase was removed to a new tube to which one-tenth volume 3M NaOAc, and three volumes ethanol was added followed by storage at -20°C for 30 minutes. Both aliquots (A and B) were then centrifuged for 10 minutes at maximum speed in a microcentrifuge to pellet the DNA. The pellets were then washed two times each with 80% ethanol and then desiccated to dryness. The dried pellets were then dissolved in 70 µl ddH₂O each.

The TdT reactions were conducted as follows. Six mixes were assembled. all mixes contained 10 mM TrisOAc (pH 7.5), 10 mM MgOAc, 50 mM KCl, and 2 mM dATP. Mixes 1 and 2 contained one pmole of untreated 34-078-01 (SEQ ID NO:86). mixes 3 and 4 contained 2 µl of aliquot A (above). mixes 5 and 6 contained 2 µl of aliquot B (above). To each 9 µl of mixes 1,3 and 5. 1 µl ddH₂O was added. to each 9 µl of mixes 2, 4, and 6. 1 µl of 20 units/µl TdT (Promega) was added. The mixes were incubated at 37°C for 1 hour and then the reaction was terminated by the addition of 5 µl 95% formamide with 10 mM EDTA and 0.05% marker dyes. Five microliters of each mixture was resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA, and imaged using with the FMBIO Image Analyzer with a 505 nm filter. The resulting imager scan is shown in Fig. 66.

In Fig. 66, lanes 1, 3 and 5 contain untreated 34-078-01 (SEQ ID NO:86), heat-degraded 34-078-01, and heat-degraded, dephosphorylated, 34-078-01, respectively incubated in the absence of TdT. Lanes 2, 4 and 6 contain, untreated 34-078-01, heat-degraded 34-078-01, and heat-degraded, dephosphorylated, 34-078-01, respectively incubated in the presence of TdT.

As shown in Fig. 66, lane 4, TdT was unable to extend thermal degradation products which contain a 3'-end phosphate group, and selectively extends molecules which have a 3'-end hydroxyl group.

EXAMPLE 30**Specific TdT Tailing Of The Products Of Invader™-Directed Cleavage With Subsequent Capture And Detection On Nitrocellulose Supports**

5 When TdT is used to extend the specific products of cleavage, one means of detecting the tailed products is to selectively capture the extension products on a solid support before visualization. This example demonstrates that the cleavage products can be selectively tailed by the use of TdT and deoxynucleotide triphosphates, and that the tailed products can be visualized by capture using a complementary oligonucleotide bound to a nitrocellulose support.

10 To extend the cleavage product produced in an Invader™-directed cleavage reaction, the following experiment was performed. Three reaction mixtures were assembled, each in a buffer of 10 mM MES (pH 6.5), 0.5% Tween-20, 0.5% NP-40. The first mixture contained 5 fmols of target DNA-M13mp18, 10 pmols of probe oligo 32-161-2 (SEQ ID NO:87; this probe oligonucleotide contains 3' ddC and a Cy3 amidite group near the 3' end), and 5 pmols of Invader™ oligonucleotide 32 161-1 (SEQ ID NO:88; this oligo contains a 3' ddC). The second mixture contained the probe and Invader™ oligonucleotides without target DNA. The third mixture was the same as the first mixture, and contained the same probe sequence, but with a 5' fluorescein label [oligo 32-161-4 (SEQ ID NO:89; this oligo contains a 3' ddC, 5' fluorescein label, and a Cy3 dye group near the 3' end)], so that the Invader™-directed cleavage products could be detected before and after cleavage by fluorescence imaging. The probe only control sample contained 10 pmols of oligo 32-161-2 (SEQ ID NO:87). Each 3 µl of enzyme mix contained 5 ng of Cleavase® DN nuclease in 7.5 mM MgCl₂. The TdT mixture (per each 4 µl) contained: 10U of TdT (Promega), 1 mM CoCl₂, 50 mM KCl, and 100 µM of dTTP. The Invader™ cleavage reaction mixtures described above were assembled in thin wall tubes, and the reactions were initiated by the addition of 3 µl of Cleavase® DN enzyme mix. The reactions were incubated at 65°C for 20 min. After cooling to 37°C, 4 µl of the TdT mix was added and the samples were incubated for 4 min at 37°C. Biotin-16-dUTP was then added to 100 µM and the samples were incubated for 50 min at 37°C. The reactions were terminated by the addition of 1 µl of 0.5 M EDTA.

25 To test the efficiency of tailing the products were run on an acrylamide gel. Four microliters of each reaction mixture was mixed with 2.6 µl of 95% formamide, 10 mM EDTA and 0.05% methyl violet and heated to 90°C for 1 min, and 3 µl were loaded on a

20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. A marker [Φ X174-*Hinf*I (fluorescein labeled)] also was loaded. After electrophoresis, the gel was analyzed using a FMBIO-100 Image Analyzer (Hitachi) equipped with a 505 nm filter. The resulting scan is shown in Fig. 67.

5 In Fig. 67, lane 1 contained the probe 32-161-2 only, without any treatment. Lanes 2 and 3 contained the products of reactions run without target DNA, without or with subsequent TdT tailing, respectively. Lanes 4 and 5 contained the products of reactions run with target DNA, probe oligo 32-161-2 (SEQ ID NO:87) and Invader™ oligo 32-161-1 (SEQ ID NO:88), without or with subsequent TdT tailing, respectively. Lanes 6 and 7 show the
10 products of reactions containing target DNA, probe oligo 32-161-4 (SEQ ID NO:89) and Invader™ oligo 32-161-1 (SEQ ID NO:88), without or with subsequent TdT tailing, respectively. Lane M contains the marker Φ X174-*Hinf*I.

The reaction products in lanes 4 and 5 are the same as those seen in lanes 6 and 7, except that the absence of a 5' fluorescein on the probe prevents detection of the released 5' product (indicated as "A" near the bottom of the gel) or the TdT extended 5' product (indicated as "B", near the top of the gel). The Cy3-labeled 3' portion of the cleaved probe is visible in all of these reactions (indicated as "C", just below the center of the gel).

To demonstrate detection of target-dependent Invader-directed cleavage products on a solid support, the reactions from lanes 3 and 5 were tested on the Universal Genecomb®
20 (Bio-Rad) which is a standard nitrocellulose matrix on a rigid nylon backing styled in a comb format, as depicted in Fig. 68. Following the manufacturer's protocol, with one modification: 10 μ l of the Invader-directed cleavage reactions were used instead the recommended 10% of a PCR. To capture the cleavage products, 2.5 pmols of the capture oligo 59-28-1 (SEQ ID NO:90) were spotted on each tooth. The capture and visualization steps were conducted
25 according to the manufacturer's directions. The results are shown in Fig. 68.

In Fig. 68, teeth numbered 6 and 7 show the capture results of reactions performed without and with target DNA present. Tooth 8 shows the kit positive control.

The darkness of the spot seen on tooth 7, when compared to tooth 6, clearly indicates that products of Invader™-directed cleavage assays may be specifically detected on solid
30 supports. While the Universal Genecomb® was used to demonstrate solid support capture in this instance, other support capture methods known to those skilled in the art would be equally suitable. For example, beads or the surfaces of reaction vessels may easily be coated with capture oligonucleotides so that they can then be used in this step. Alternatively, similar

solid supports may easily be coated with streptavidin or antibodies for the capture of biotin- or hapten-tagged products of the cleavage/tailing reaction. In any of these embodiments, the products may be appropriately visualized by detecting the resulting fluorescence, chemiluminescence, colorimetric changes, radioactive emissions, optical density change or any other distinguishable feature of the product.

EXAMPLE 31

Comparison Of The Effects Of Invasion Length and 5' Label Of The Probe On Invader™-Directed Cleavage By The Cleavase® A/G and *Pfu* FEN-1 Nucleases

To investigate the effect of the length of invasion as well as the effect of the type of dye on ability of *Pfu* FEN-1 and the Cleavase® A/G nuclease to cleave 5' arms, the following experiment was performed. Three probes of similar sequences labeled with either fluorescein, TET, or Cy3, were assembled in reactions with three Invader™ oligonucleotides which created overlapping target hybridization regions of eight, five, and three bases along the target nucleic acid, M13mp18.

The reactions were conducted as follows. All conditions were performed in duplicate. Enzyme mixes for *Pfu* FEN-1 and the Cleavase® A/G nuclease were assembled. Each 2 µl of the *Pfu* FEN-1 mix contained 100 ng of *Pfu* FEN-1 (prepared as described in Ex. 28) and 7.5 mM MgCl₂. Each 2 µl of the Cleavase® A/G mix contained 5.3 ng of the Cleavase® A/G nuclease and 4.0 mM MnCl₂. Six master mixes containing buffer, M13mp18, and Invader™ oligonucleotides were assembled. Each 7 µl of mixes 1-3 contained 1 fmol M13mp18, 10 pmoles Invader™ oligonucleotide [34-078-4 (SEQ ID NO:39), 24-181-2 (SEQ ID NO:91), or 24-181-1 (SEQ ID NO:92) in 10 mM MOPS (pH 7.5), 150 mM LiCl. Each 7 µl of mixes 4-6 contained 1 fmol of M13mp18, 10 pmoles of Invader™ oligonucleotide [34-078-4 (SEQ ID NO:39), 24-181-2 (SEQ ID NO:91), or 24-181-1 (SEQ ID NO:92)] in 10 mM Tris (pH 8.0). Mixtures 1-6 were then divided into three mixtures each, to which was added either the fluorescein-labeled probe (oligo 34-078-01; SEQ ID NO:86), the Cy3-labeled probe (oligo 43-20; SEQ ID NO:93) or the TET-labeled probe (oligo 90; SEQ ID NO:32 containing a 5' TET label). Each 7 µl of all mixtures contained 10 pmoles of corresponding probe. The DNA solutions described above were covered with 10 µl of ChillOut® evaporation barrier and brought to 68°C.

The reactions made from mixes 1-3 were started with 2 μ l of the Cleavase® A/G nuclease mix, and the reactions made from mixes 4-6 were started with 2 μ l of the *Pfu* FEN-1 mix. After 30 minutes at 68°C, the reactions were terminated by the addition of 8 μ l of 95% formamide with 10 mM EDTA and 0.05% marker dyes. Samples were heated to 90°C for 1 minute immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA. The products of the cleavage reactions were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. Results from the fluorescein-labeled probe are shown in Fig. 69, results from the Cy3-labeled probe in Fig. 70, and results from the TET-labeled probe in Fig. 71. In each of these figures the products of cleavage by Cleavase® A/G are shown in lanes 1-6 and the products of cleavage by *Pfu*FEN-1 are shown in lanes 7-12. In each in case the uncut material appears as a very dark band near the top of the gel, indicated by a "U" on the left. The products of cleavage directed by Invader oligonucleotides with 8, 5 or 3 bases of overlap (*i.e.*, the "X" region was 8, 5, or 3 nt long) are shown in the first, second and third pair of lanes in each set, respectively and the released labeled 5' ends from these reactions are indicated by the numbers 8, 5, and 3 on the left. Note that in the cleavage reactions shown in Fig. 70 the presence of the positively charged Cy3 dye causes the shorter products to migrate more slowly than the larger products. These products do not contain any additional positive charges, *e.g.*, amino modifications as used in Example 23, and thus still carry a net negative charge, and migrate towards the positive electrode in a standard electrophoresis run.

It can be seen from these data that the Cleavase® A/G and *Pfu* FEN-1 structure-specific nucleases respond differently to both dye identity and to the size of the piece to be cleaved from the probe. The *Pfu* FEN-1 nuclease showed much less variability in response to dye identity than did the Cleavase® A/G nuclease, showing that any dye would be suitable for use with this enzyme. In contrast, the amount of cleavage catalyzed by the Cleavase® A/G nuclease varied substantially with dye identity. Use of the fluorescein dye gave results very close to those seen with the *Pfu* FEN-1 nuclease, while the use of either Cy3 or TET gave dramatically reduced signal when compared to the *Pfu* FEN-1 reactions. The one exception to this was in the cleavage of the 3 nt product carrying a TET dye (lanes 5 and 6, Fig. 71), in which the Cleavase® A/G nuclease gave cleavage at the same rate as the *Pfu* FEN-1 nuclease. These data indicate that, while Cleavase® A/G may be used to cleave probes labeled with

these other dyes, the *Pfu* FEN-1 nuclease is a preferred nuclease for cleavage of Cy3- and TET-labeled probes.

EXAMPLE 32

5 Examination Of The Effects Of A 5' Positive Charge On The Rate Of Invasive Cleavage Using The Cleavase® A/G Or *Pfu* FEN-1 Nucleases

To investigate whether the positive charges on 5' end of probe oligonucleotides containing a positively charged adduct(s) (*i.e.*, charge reversal technology or CRT probes as described in Ex. 23 and 24 have an effect on the ability of the Cleavase® A/G or *Pfu* FEN-1 nucleases to cleave the 5' arm of the probe, the following experiment was performed.

Two probe oligonucleotides having the following sequences were utilized in Invader™ reactions: Probe 34-180-1: (N-Cy3)_{T_{NH2}T_{NH2}}CCAGAGCCTAATTGCCC
AGT(N-fluorescein)A, where N represents a spacer containing either the Cy3 or fluorescein group (SEQ ID NO:94) and Probe 34-180-2: 5'-(N-TET)TTCCAGAGCC
TAATTTGCCAGT-(N-fluorescein)A, where N represents a spacer containing either the TET or fluorescein group (SEQ ID NO:95). Probe 34-180-1 has amino-modifiers on the two 5' end T residues and a Cy3 label on the 5' end, creating extra positive charges on the 5' end. Probe 34-180-2 has a TET label on the 5' end, with no extra positive charges. The
20 fluorescein label on the 3' end of probe 34-180-1 enables the visualization of the 3' cleaved products and uncleaved probes together on an acrylamide gel run in the standard direction (*i.e.*, with the DNA migrating toward the positive electrode). The 5' cleaved product of probe 34-180-1 has a net positive charge and will not migrate in the same direction as the uncleaved probe, and is thus visualized by resolution on a gel run in the opposite direction
25 (*i.e.*; with this DNA migrating toward the negative electrode).

The cleavage reactions were conducted as follows. All conditions were performed in duplicate. Enzyme mixes for the *Pfu* FEN-1 and Cleavase® A/G nucleases were assembled. Each 2 µl of the *Pfu* FEN-1 mix contained 100 ng of *Pfu* FEN-1 (prepared as described in Ex. 28) and 7.5 mM MgCl₂. Each 2 µl of the Cleavase® A/G nuclease mix contained 26.5
30 ng of Cleavase® A/G nuclease and 4.0 mM MnCl₂. Four master mixes containing buffer, M13mp18, and Invader™ oligonucleotides were assembled. Each 7 µl of mix 1 contained 5 fmol M13mp18, 10 pmoles Invader™ oligonucleotide 123 (SEQ ID NO:96) in 10 mM HEPES (pH 7.2). Each 7 µl of mix 2 contained 1 fmol M13mp18, 10 pmoles Invader™

oligonucleotide 123 in 10 mM HEPES (pH 7.2). Each 7 μ l of mix 3 contained 5 fmol M13mp18, 10 pmoles Invader™ oligonucleotide 123 in 10 mM HEPES (pH 7.2), 250 mM KGlu. Each 7 μ l of mix 4 contained 1 fmol M13mp18, 10 pmoles Invader™ oligonucleotide 123 in 10 mM HEPES (pH 7.2), 250 mM KGlu. For every 7 μ l of each mix, 10 pmoles of either probe 34-180-1 (SEQ ID NO:94) or probe 34-180-2 (SEQ IDNO:95) was added. The DNA solutions described above were covered with 10 μ l of ChillOut® evaporation barrier and brought to 65°C. The reactions made from mixes 1-2 were started by the addition of 2 μ l of the *Pfu* FEN-1 mix, and the reactions made from mixes 3-4 were started by the addition of 2 μ l of the Cleavase® A/G nuclease mix. After 30 minutes at 65°C, the reactions were terminated by the addition of 8 μ l of 95% formamide containing 10 mM EDTA. Samples were heated to 90°C for 1 minute immediately before electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA and a 20% native acrylamide gel (29:1 cross-linked) in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4 mM EDTA.

The products of the cleavage reactions were visualized following electrophoresis by the use of a Hitachi FMBIO fluorescence imager. The resulting images are shown in Fig. 72. Fig. 72A shows the denaturing gel which was run in the standard electrophoresis direction, and Fig. 72B shows the native gel which was run in the reverse direction. The reaction products produced by *Pfu* FEN-1 and Cleavase® A/G nucleases are shown in lanes 1-8 and 9-16, respectively. The products from the 5 fmol M13mp18 and 1 fmol M13mp18 reactions are shown in lanes 1-4, 9-12 (5 fmol) and 5-8, 13-16 (1 fmol). Probe 34-180-1 is in lanes 1-2, 5-6, 9-10, 13-14 and probe 34-180-2 is in lanes 3-4, 7-8, 11-12, 15-16.

The fluorescein-labeled 3' end fragments from all cleavage reactions are shown in Fig. 72A, indicated by a "3'" mark at the left. The 3 nt 5' TET-labeled products are not visible in this figure, while the 5' Cy3-labeled products are shown in Fig. 72B.

The 3' end bands in Fig. 72A can be used to compare the rates of cleavage by the different enzymes in the presence of the different 5' end labels. It can be seen from this band that regardless of the amount of target nucleic acid present, both the *Pfu* FEN-1 and the Cleavase® A/G nucleases show more product from the 5' TET-labeled probe. With the *Pfu* FEN-1 nuclease this preference is modest, with only an approximately 25 to 40% increase in signal. In the case of the Cleavase® A/G nuclease, however, there is a strong preference for the 5' TET label. Therefore, although when the charge reversal method is used to resolve the products, a substantial amount of product is observed from the Cleavase® A/G nuclease-

catalyzed reactions, the *Pfu* FEN-1 nuclease is a preferred enzyme for cleavage of Cy3-labeled probes.

EXAMPLE 33

The Use Of Universal Bases In The Detection Of Mismatches By Invader™-Directed Cleavage

The term "degenerate base" refers to a base on a nucleotide that does not hydrogen bond in a standard "Watson-Crick" fashion to a specific base complement, *i.e.*, A to T and G to C. For example, the inosine base can be made to pair via one or two hydrogen bonds to all of the natural bases (the "wobble" effect) and thus is called degenerate. Alternatively, a degenerate base may not pair at all; this type of base has been referred to as a "universal" base because it can be placed opposite any nucleotide in a duplex and, while it cannot contribute stability by base-pairing, it does not actively destabilize by crowding the opposite base. Duplexes using these universal bases are stabilized by stacking interactions only. Two examples of universal bases, 3-nitropyrrole and 5-nitroindole, are shown in Fig. 73. In hybridization, placement of a 3-nitropyrrole three bases from a mismatch position enhances the differential recognition of one base mismatches. The enhanced discrimination seems to come from the destabilizing effect of the unnatural base (*i.e.*, an altered T_m in close proximity to the mismatch). To test this same principle as a way of sensitively detecting mismatches using the Invader™-directed cleavage assay, Invader™ oligonucleotides were designed using the universal bases shown in Fig. 73, in the presence or absence of a natural mismatch. In these experiments, the use of single nitropyrrole bases or pairs of nitroindole bases that flank the site of the mismatch were examined.

The target, probe and Invader™ oligonucleotides used in these assays are shown in Fig. 74. A 43 nucleotide oligonucleotide (oligo 109; SEQ ID NO:97) was used as the target. The probe oligonucleotide (oligo 61; SEQ ID NO:50) releases a net positively charged labeled product upon cleavage. In Fig. 74, the Invader™ oligonucleotide is shown schematically above the target oligonucleotide as an arrow; the large arrowhead indicates the location of the mismatch between the Invader™ oligos and the target. Under the target oligonucleotide, the completely complementary, all natural (*i.e.*, no universal bases) Invader™ oligo (oligo 67; SEQ ID NO:51) and a composite of Invader™ oligos containing universal bases ("X") on either side of the mismatch ("M") are shown. The following Invader™ oligos were

employed: oligo 114 (SEQ ID NO:98) which contains a single nt mismatch: oligo 115 (SEQ ID NO:99) which contains two 5-nitroindole bases and no mismatch: oligo 116 (SEQ ID NO:100) which contains two 5-nitroindole bases and a single nt mismatch: oligo 112 (SEQ ID NO:101) which contains one 3-nitropyrrole base and no mismatch: oligo 113 (SEQ ID NO:102) which contains one 5-nitropyrrole base and a single nt mismatch: and oligo 67 (SEQ ID NO:51) which is completely complementary to the target.

The Invader™-directed cleavage reactions were carried out in 10 µl of 10 mM MOPS (pH 7.2), 100 mM KCl, containing 1 µM of the appropriate invading oligonucleotide (oligos 67, 112-116), 10 nM synthetic target 109, 1 µM Cy-3 labeled probe 61 and 2 units of Cleavase® DV (prepared as described in Ex. 27). The reactions were overlaid with Chill-Out® liquid wax, brought to the appropriate reaction temperature, 52°C, 55°C. or 58°C and initiated with the addition of 1 µl of 40 mM MnCl₂. Reactions were allowed to proceed for 1 hour and were stopped by the addition of 10 µl formamide. One fourth of the total volume of each reaction was loaded onto 20% non-denaturing polyacrylamide gels which were electrophoresed in the reverse direction. The products were visualized using an Hitachi FMBIO-100 fluorescent scanner using a 585 nm filter. The resulting images are shown in Figs. 75A-C. In each panel, lanes 1-6 contain reactions products from reactions using Invader™ oligo 67, 114, 115, 116, 112 and 113, respectively. Reactions run at 52°C, 55°C and 58°C are shown in Panels A, B and C, respectively.

These data show that two flanking 5-nitroindoles display a significantly greater differentiation than does the one 3-nitropyrrole system, or the all natural base hybridization, and this increased sensitivity is not temperature dependent. This demonstrates that the use of universal bases is a useful means of sensitively detecting single base mismatches between the target nucleic acid and the complex of detection oligonucleotides of the present invention.

EXAMPLE 34

Detection Of Point Mutations in The Human *Ras* Oncogene Using A Miniprobe

It is demonstrated herein that very short probes can be used for sensitive detection of target nucleic acid sequences (Ex. 37). In this example it is demonstrated that the short probes work very poorly when mismatched to the target, and thus can be used to distinguish a given nucleic acid sequence from a close relative with only a single base difference. To test this system synthetic human *ras* oncogene target sequences were created that varied from each

other at one position. Oligonucleotide 166 (SEQ ID NO:103) provided the wild-type *ras* target sequence. Oligonucleotide 165 (SEQ ID NO:104) provided the mutant *ras* target sequence. The sequence of these oligonucleotides are shown in Fig. 76, and the site of the sequence variation in the site corresponding to codon 13 of the *ras* gene is indicated. The

5 Invader™ oligonucleotide (oligo 162) has the sequence:

5'-G₅C₅T₅C₅A₅A₅G₅G₅C₅ACTCTTGCCTACGA-3' (SEQ ID NO:105), where the "S" indicates thiol linkages [*i.e.*, these are 2'-deoxynucleotide-5'-O-(1-thiomonophates)]. The miniprobe

(oligo 161) has the sequence: 5'-(N-Cy3) T_{NH2}T_{NH2}CACCAG-3' (SEQ ID NO:106) and is designed to detect the mutant *ras* target sequence (*i.e.*, it is completely complementary to

10 oligo 165). The stacker oligonucleotide (oligo 164) has the sequence: 5'-C₅T₅C₅C₅A₅A₅C₅T₅A₅CCACAAGTTTATATTTCAG-3' (SEQ ID NO:107). A schematic showing the assembly of these oligonucleotides into a cleavage structure is depicted in Fig. 76.

Each cleavage reaction contained 100 nM of both the invading (oligo 162) and stacking (oligo 164) oligonucleotides, 10 μM Cy3-labeled probe (oligo 161) and 100 pM of
 15 either oligo 165 or oligo 166 (target DNA) in 10 μl of 10 mM HEPES (pH 7.2), 250 mM KGlu, 4 mM MnCl₂. The DNA mixtures were overlaid with mineral oil, heated to 90°C for 15 sec then brought to a reaction temperature of 47°, 50°, 53° or 56°C. Reactions were initiated by the addition of 1 μl of 100 ng/μl Pfu FEN-1. Reactions were allowed to proceed for 3 hours and stopped by the addition of 10 μl formamide. One fourth of the total volume
 20 of each reaction was loaded onto a 20% non-denaturing polyacrylamide gel which was electrophoresed in the reverse direction. The gel was scanned using an Hitachi FMBIO-100 fluorescent scanner fitted with a 585 nm filter, and the resulting image is shown in Fig. 77.

In Fig. 77, for each reaction temperature tested, the products from reactions containing either the mutant *ras* target sequence (oligo 165) or the wild-type (oligo 166) are shown.

25 These data demonstrate that the miniprobe can be used to sensitively discriminate between sequences that differ by a single nucleotide. The miniprobe was cleaved to produce a strong signal in the presence of the mutant target sequence, but little or no miniprobe was cleaved in the presence of the wild-type target sequence. Furthermore, the discrimination between closely related targets is effective over a temperature range of at least 10°C, which is
 30 a much broader range of temperature than can usually be tolerated when the selection is based on hybridization alone (*e.g.*, hybridization with ASOs). This suggests that the enzyme may be a factor in the discrimination, with the perfectly matched miniprobe being the preferred

substrate when compared to the mismatched miniprobe. Thus, this system provides sensitive and specific detection of target nucleic acid sequences.

EXAMPLE 35

5 Effects of 3' End Identity On Site Of Cleavage Of A Model Oligonucleotide Structure

As described in the examples above, structure-specific nucleases cleave near the junction between single-stranded and base-paired regions in a bifurcated duplex, usually about one base pair into the base-paired region. It was shown in Example 10 that thermostable 5' nucleases, including those of the present invention (e.g., Cleavase® BN nuclease, Cleavase® A/G nuclease), have the ability to cleave a greater distance into the base paired region when provided with an upstream oligonucleotide bearing a 3' region that is homologous to a 5' region of the subject duplex, as shown in Fig. 26. It has also been determined that the 3' terminal nucleotide of the invader oligonucleotide may be unpaired to the target nucleic acid, and still shift cleavage the same distance into the down stream duplex as when paired. It is shown in this example that it is the base component of the nucleotide, not the sugar or phosphate, that is necessary to shift cleavage.

Figs. 78A and B shows a synthetic oligonucleotide which was designed to fold upon itself which consists of the following sequence: 5'-GTTCTCTGCTCTCTGGTC
20 GCTGTCTCGCTTGTGAAACAAGCGAGACAGCGTGGTCTCTCG-3' (SEQ ID NO:29). This oligonucleotide is referred to as the "S-60 Hairpin." The 15 basepair hairpin formed by this oligonucleotide is further stabilized by a "tri-loop" sequence in the loop end (i.e., three nucleotides form the loop portion of the hairpin) [Hiraro, I. *et al.* (1994) *Nucleic Acids Res.* 22(4): 576]. Fig. 78B shows the sequence of the P-15 oligonucleotide (SEQ ID NO:30) and the location of the region of complementarity shared by the P-15 and S-60 hairpin oligonucleotides. In addition to the P-15 oligonucleotide shown, cleavage was also tested in the presence of the P-14 oligonucleotide (SEQ ID NO:108) (P-14 is one base shorter on the 3' end as compared to P-15), the P-14 with an abasic sugar (P-14d; SEQ ID NO:109) and the P14 with an abasic sugar with a 3' phosphate (P-14dp; SEQ ID NO:110). A P-15 oligo with a 3' phosphate, P-15p (SEQ ID NO:111) was also examined. The black arrows shown in Fig. 78 indicate the sites of cleavage of the S-60 hairpin in the absence (top structure; A) or presence (bottom structure; B) of the P-15 oligonucleotide.

The S-60 hairpin molecule was labeled on its 5' end with fluorescein for subsequent detection. The S-60 hairpin was incubated in the presence of a thermostable 5' nuclease in the presence or the absence of the P-15 oligonucleotide. The presence of the full duplex which can be formed by the S-60 hairpin is demonstrated by cleavage with the Cleavase® BN 5' nuclease, in a primer-independent fashion (*i.e.*, in the absence of the P-15 oligonucleotide). The release of 18 and 19-nucleotide fragments from the 5' end of the S-60 hairpin molecule showed that the cleavage occurred near the junction between the single and double stranded regions when nothing is hybridized to the 3' arm of the S-60 hairpin (Fig. 27, lane 2).

The reactions shown in Fig. 78C were conducted in 10 µl 1X CFLP buffer with 1 mM MnCl₂ and 50 mM K-Glutamate, in the presence of 0.02 µM S-60, 0.5 µM Invader™ oligonucleotide and 0.01 ng per µl Cleavase® BN nuclease. Reactions were incubated at 40°C for 5 minutes and stopped by the addition of 8 µl of stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). Samples were heated to 75°C for 2 min immediately before electrophoresis through a 15% acrylamide gel (19:1 cross-linked), with 7 M urea, in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA. Gels were then analyzed with a FMBIO-100 Image Analyzer (Hitachi) equipped with 505 nm filter. The resulting image is shown in Fig. 78C.

In Fig. 78C lane 1 contains products from the no enzyme control; lane 2 contains products from a reaction run in the absence of an Invader™ oligo; lanes 3-6 contain products from reactions run the presence of the P-14d, P-14dp, P-15 and P-15p Invader™ oligos, respectively.

From the data shown in Fig. 78C, it can be seen that the use of the P-15 Invader™ oligonucleotide produces a shift in the cleavage site, while the P14 Invader™ oligonucleotide with either a ribose (P14d) or a phosphorylated ribose (P14dp) did not. This indicates that the 15th residue of the Invader™ oligonucleotide must have the base group attached to promote the shift in cleavage. Interestingly, the addition of phosphate to the 3' end of the P15 oligonucleotide apparently reversed the shifting of cleavage site. The cleavage in this lane may in fact be cleavage in the absence of an Invader™ oligonucleotide as is seen in lane 2. In experiments with 5' dye-labeled Invader™ oligonucleotides with 3' phosphate groups these oligonucleotides have been severely retarded in gel migration, suggesting that either the enzyme or another constituent of the reaction (*e.g.*, BSA) is able to bind the 3' phosphate irrespective of the rest of the cleavage structure. If the Invader™ oligonucleotides are indeed

being sequestered away from the cleavage structure, the resulting cleavage of the S-60 hairpin would occur in a "primer-independent" fashion, and would thus not be shifted.

In addition to the study cited above, the effects of other substituents on the 3' ends of the Invader™ oligonucleotides were investigated in the presence of several different enzymes, and in the presence of either Mn⁺⁺ or Mg⁺⁺. The effects of these 3' end modifications on the generation of cleaved product are summarized in the following table. All of modifications were made during standard oligonucleotide synthesis by the use of controlled pore glass (CPG) synthesis columns with the listed chemical moiety provided on the support as the synthesis starting residue. All of these CPG materials were obtained from Glen Research Corp. (Sterling, VA).

Fig. 79 provides the structures for the 3' end substituents used in these experiments.

TABLE 3

Modification Studies At 3' End Of Invader Oligo

3'-End Modification	Extension By Terminal Transferase	Effect on Invader Rxn. (As Invader) Enzyme:Condition - Effect
3' phosphate Glen part # 20-2900-42	no	A:5 - inhibits reaction, no detectable activity
3' acridine Glen part # 20-2973-42	yes, poorly	A:5 - decrease in activity, <10% B:5 - decrease in activity, < 10% B:4 - decrease in activity, < 10% C:1 - decrease in activity, <10% C:2 - decrease in activity, ~20% C:4 - decrease in activity, ~ 50% C:3 - decrease in activity, <5%
3' carboxylate Glen part # 20-4090-42	no	A:1 - decrease in activity, ~50% activity shift in cleavage site C:3 - reduces rate, <10% activity
3' nitropyrrole Glen part # 20-2143-42	yes	A:5 - increase in activity, ~2X
3' nitroindole Glen part # 20-2144-42	yes	A:5 - decrease in activity, ~33% activity
3' arabinose Glen part # 10-4010-90	yes	A:5 - decrease in activity, ~50% activity
3'dideoxyUTP- fluorescein	no	A:5 - decrease in activity, ~40% activity
3'-3' linkage Glen part # 20-0002-01	no	A:1 - equivalent cleavage activity shift in cleavage site C:3 - decrease in activity, ~25% activity
3' glyceryl Glen part # 20-2902-42	yes, very poorly	C:3 - decrease in activity, ~30% activity loss of specificity of cleavage (2 sites)
3' amino modifier C7 Glen part # 20-2957-42	yes	C:3 - decrease in activity, ~30% activity loss of specificity, multiple sites
3'deoxy, 2'OH Glen part # 20-2104-42	yes, very poorly	A:5 - decrease in activity, <20% activity B:5 - decrease in activity, <20% activity B:3 - decrease in activity, <20% activity C:1 - equivalent activity C:2 - equivalent activity C:4 - ? increase in activity C:3 - decrease in activity, ~40% activity

Enzymes:

- A) Cleavase® DV nuclease
B) Cleavase® BN nuclease
C) *Pfu* FEN-1

Condition:

- 1) 4mM MnCl₂, 150mM LiCl
2) 4mM MnCl₂, 50mM KCl
3) 7.5mM MgCl₂, no monovalent
4) 4mM MgCl₂, 50mM KCl
5) 10mM MgOAc, 50mM KCl

It can be seen from these data that many different modifications can be used on the 3' end of the Invader™ oligonucleotide without detriment. In various embodiments of the present invention, such 3' end modifications may be used to block, facilitate, or otherwise alter the hybridization characteristics of the Invader™ oligonucleotide, (e.g., to increase discrimination against mismatches, or to increase tolerance of mismatches, or to tighten the association between the Invader™ oligonucleotide and the target nucleic acid). Some substituents may be used to alter the behavior of the enzyme in recognizing and cleaving within the assembled complex.

Altered 3' ends may also be used to prevent extension of the Invader™ oligonucleotide by either template-dependent or template-independent nucleic acid polymerases. The use of otherwise unmodified dideoxynucleotides (*i.e.*, without attached dyes or other moieties) are a particularly preferred means of blocking extension of Invader™ oligonucleotides, because they do not decrease cleavage activity, and they are absolutely unextendable.

EXAMPLE 36

Effect Of Probe Concentration, Temperature And A Stacker Oligonucleotide On The Cleavage Of Miniprobcs By Invader™-Directed Cleavage

The stacker oligonucleotides employed to form cleavage structures may serve two purposes in the detection of a nucleic acid target using a miniprobe. The stacker oligonucleotide may help stabilize the interaction of the miniprobe with the target nucleic acid, leading to greater accumulation of cleaved probe. In addition, the presence of this oligo in the complex elongates the duplex downstream of the cleavage site, which may enhance the cleavage activity of some of the enzymes of the present invention. An example of different preferences for the length of this duplex by different structure-specific nucleases is seen in the comparison of the Cleavase® BN nuclease and the *Mja* FEN-1 nuclease cleavage of 8 bp and 12 bp duplex regions in Fig. 65. Increased affinity of the enzyme for the cleavage structure also results in increased accumulation of cleaved probe during reactions done for a set amount of time.

The amount of miniprobe binding to the target is also affected by the concentration of the miniprobe in the reaction mixture. Even when a miniprobe is only marginally likely to hybridize (*e.g.*, when the reaction is performed at temperatures in excess of the expected

melting temperature of the probe/target duplex), the amount of probe on the target at any given time can be increased by using high concentrations of the miniprobe.

The need for a stacker oligonucleotide to enhance cleavage of the miniprobe was examined at both low and high probe concentrations. The reactions were carried out in 10 μ l of 10 mM HEPES (pH 7.2), 250 mM K₂Glu, 4 mM MnCl₂, containing 100 nM of both the
5 invading (oligo 135; SEQ ID NO:112) and stacking oligonucleotides (oligo 147; SEQ ID NO:113) and 100 pM ssM13 DNA. The reactions were overlayed with mineral oil, heated to 90°C for 15 sec then brought to the reaction temperature. Reactions were performed at 35°, 40°, 45°, 50°, 55°, 60°, and 65°C. The cleavage reactions were initiated by the addition of 1
10 μ l of 100 ng/ μ l *Pfu* FEN-I and 1 μ l of varying concentrations of Cy-3 labeled 142 miniprobe oligonucleotide (SEQ ID NO:114). Reactions were allowed to proceed for 1 hour and stopped by the addition of 10 μ l formaldehyde. One fourth of the total volume of each reaction was loaded onto 20% non-denaturing polyacrylamide gels which were electrophoresed in the reverse direction. Gels were visualized using an Hitachi FMBIO-100
15 fluorescent scanner using a 585 nm filter. The fluorescence in each product band was measured and the graph shown in Fig. 80 was created using a Microsoft Excel spreadsheet.

The data summarized in Fig. 80 showed that the concentration of the miniprobe had a significant effect on the final measure of product, showing dramatic increases as the concentration was raised. Increases in the concentration of the miniprobe also shifted the
20 optimum reaction temperature upward. It is known in the art that the concentration of the complementary strands in a hybridization will affect the apparent T_m of the duplex formed between them. More significantly to the methods and compositions of the present invention is the fact that the presence of the stacker oligonucleotide has a profound influence on the cleavage rate of the miniprobe at all probe concentrations. At each of the probe
25 concentrations the presence of the stacker as much as doubled the signal from the cleavage product. This demonstrated the utility of using the stacker oligonucleotide in combination with the miniprobos described herein.

EXAMPLE 37**The Presence of A Mismatch In The Invader™ Oligonucleotide Decreases The Cleavage Activity Of The Cleavase® A/G Nuclease**

5 In any nucleic acid detection assay it is of additional benefit if the assay can be made to sensitively detect minor differences between related nucleic acids. In the following experiment, model cleavage substrates were used that were identical except for the presence or absence of a mismatch near the 3' end of the Invader™ oligonucleotide when hybridized to the model target nucleic acid. The effect of a mismatch in this region on the accumulation of
10 cleaved probe was then assessed.

 To demonstrate the effect of the presence of a mismatch in the Invader™ oligonucleotide on the ability of the Cleavase® A/G nuclease to cleave the probe oligonucleotide in an Invader™ assay the following experiment was conducted. Cleavage of the test oligonucleotide IT-2 (SEQ ID NO:115) in the presence of Invader™ oligonucleotides
15 IT-1 (SEQ ID NO:116) and IT-1A4 (SEQ ID NO:117). Oligonucleotide IT-1 is fully complementary to the 3' arm of IT-2, whereas oligonucleotide IT-1A4 has a T->A substitution at position 4 from the 3' end that results in an A/A mismatch in the Invader™-target duplex. Both the matched and mismatched Invader™ oligonucleotides would be expected to hybridize at the temperature at which the following reaction was performed.
20 Fig. 81 provides a schematic showing IT-1 annealed to the folded IT-2 structure and showing IT-1A4 annealed to the folded IT-2 structure.

 The reactions were conducted as follows. Test oligonucleotide IT-2 (0.1 μM), labeled at the 5' end with fluorescein (Integrated DNA Technologies), was incubated with 0.26 ng/μl Cleavase® AG in 10 μl of CFLP® buffer with 4 mM MgCl₂, in the presence of 1 μM IT-1
25 or IT-1A4 at 40°C for 10 min; a no enzyme control was also run. Samples were overlaid with 15 μl Chill-Out® liquid wax to prevent evaporation. Reactions were stopped by addition of 4 μl stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). The cleavage products were separated on a 20% denaturing polyacrylamide gel and analyzed with the FMBIO-100 Image Analyzer (Hitachi) equipped with 505 nm filter. The resulting image is
30 shown in Fig. 82.

 In Fig. 82, lane 1 contains reaction products from the no enzyme control and shows the migration of the uncut IT-2 oligo; lanes 2-4 contain products from reactions containing no Invader™ oligo, the IT-1 Invader™ oligo and the IT-1A4 Invader™ oligo, respectively.

These data show that cleavage is markedly reduced by the presence of the mismatch, even under conditions in which the mismatch would not be expected to disrupt hybridization. This demonstrates that the invader oligonucleotide binding region is one of the regions within the complex in which can be used for mismatch detection, as revealed by a drop in the
5 cleavage rate.

EXAMPLE 38

Comparison Of The Activity Of The *Pfu* FEN-1 And *Mja* FEN-1 Nucleases In The Invader™ Reaction

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To compare the activity of the *Pfu* FEN-1 and the *Mja* FEN-1 nucleases in Invader™ reaction the following experiment was performed. A test oligonucleotide IT3 (SEQ ID NO:118) that forms an Invader-Target hairpin structure and probe oligonucleotide PR1 (SEQ ID NO:119) labeled at the 5' end with fluorescein (Integrated DNA Technologies) were
15 employed in Invader™ assays using either the *Pfu* FEN-1 or the *Mja* FEN-1 nucleases.

The assays were conducted as follows. *Pfu* FEN-1 (13 ng/μl) and *Mja* FEN-1 (10 ng/μl) (prepared as described in Ex. 28) were incubated with the IT3 (0.1 nM) and PR1 (2 and 5 μM) oligonucleotides in 10 μL CFLP® buffer, 4 mM MgCl₂, 20 mg/ml tRNA at 55°C for 41 min. Samples were overlaid with 15 μl Chill-Out® evaporation barrier to prevent
20 evaporation. Reactions were stopped by addition of 70 μl stop buffer (95% formamide, 20 mM EDTA, 0.02% methyl violet). Reaction products (1 μl) were separated on a 20% denaturing polyacrylamide gel, visualized using a fluoroimager and the bands corresponding to the probe and the product were quantitated. The resulting image is shown in Fig. 83. In Fig. 83, the turnover rate per target per minute is shown below the image for each nuclease at
25 each concentration of probe and target tested.

It was demonstrated in Example 32 that the use of the *Pfu* FEN-1 structure-specific nuclease in the Invader™-directed cleavage reaction resulted in a faster rate of product accumulation than did the use of the Cleavase® A/G. The data presented here demonstrates that the use of *Mja* FEN-1 nuclease with the fluorescein labeled probe further increases the
30 amount of product generated by an average of about 50%, demonstrating that, in addition to the *Pfu* FEN-1 nuclease, the *Mja* FEN-1 nuclease is a preferred structure-specific nuclease for the detection of nucleic acid targets by the method of the present invention.

EXAMPLE 39**Detection Of RNA Target Nucleic Acids Using
Miniprobe And Stacker Oligonucleotides**

5 In addition to the detection of the M13 DNA target material described above, a miniprobe/stacker system was designed to detect the HCV-derived RNA sequences described in Example 19. A probe of intermediate length, either a long mid-range or a short standard probe, was also tested. The miniprobe used (oligo 42-168-1) has the sequence: 5'-TET-CCGGTCGTCCTGG-3' (SEQ ID NO:120), the stacker oligonucleotide used (oligo 32-085) with this miniprobe has the sequence: 5'-CAATTCGGGTGTACTACCGGTTCC-3' (SEQ ID NO:121). The slightly longer probe, used without a stacker (oligo 42-088), has the sequence: 5'-TET-CCGGTCGTCCTGGCAA-3' (SEQ ID NO:122). The Invader™ oligonucleotide used with both probes has the sequence: 5'-GTTTATCCAAGAAAGGACCCGGTC-3' (SEQ ID NO:47). The reactions included 50 fmole of target RNA, 10 pmole of the Invader™ oligonucleotide and 5 pmole of the miniprobe oligonucleotide in 10 µl of buffer containing 10 mM MES, pH 6.5 with 150 mM LiCl, 4 mM MnCl₂, 0.05% each Tween-20 and NP-40, and 39 units of RNasin (Promega). When used, 10 pmoles of the stacker oligonucleotide was added. These components were combined, overlaid with Chillout® evaporation barrier, and warmed to 50°C; the reactions were started by the addition of 5 polymerase units of DNAPT_h, to a final reaction volume of 10 µl. After 30 minutes at 50°C, reactions were stopped by the addition of 8 µl of 95% formamide, 10 mM EDTA and 0.02% methyl violet. The samples were heated to 90°C for 1 minute and 2.5 µl of each of these reactions were resolved by electrophoresis through a 20% denaturing polyacrylamide (19:1 cross link) with 7M urea in a buffer of 45 mM Tris-Borate, pH 8.3, 1.4 mM EDTA, and the labeled reaction products were visualized using the FMBIO-100 Image Analyzer (Hitachi). The resulting image is shown in Fig. 84.

 In Fig. 84, lanes 1 and 2 show the products of reactions containing the HCV Invader™ oligonucleotide and the longer probe (oligo 42-088), without and with the target RNA present, respectively. Lanes 3, 4, and 5 show the products of reactions containing the Invader™ oligonucleotide and the shorter probe (oligo 42-168-1). Lane 3 is a control reaction without target RNA present, while lanes 4 and 5 have the target, but are without or with the stacker oligonucleotide, respectively.

Under these conditions the slightly longer (16 nt) probe oligonucleotide was cleaved quite easily without the help of a stacker oligonucleotide. In contrast, the shorter probe (13 nt) required the presence of the stacker oligonucleotide to produce detectable levels of cleavage. These data show that the miniprobe system of target detection by Invader™-directed cleavage is equally applicable to the detection of RNA and DNA targets. In addition, the comparison of the cleavage performance of longer and shorter probes in the absence of a stacker oligonucleotide give one example of the distinction between the performance of the miniprobe/stacker system and the performance of the mid-range and long probes in the detection of nucleic acid targets.

EXAMPLE 40

Effect Of An Unpaired 3' Tail On Transcription From A Complete (Un-Nicked) Promoter

In designing the method of transcription-based visualization of the products of Invader™-directed cleavage, it was first necessary to assess the effect of a 3' tail on the efficiency of transcription from a full length promoter. The duplexes tested in this example are shown at the bottom of Fig. 93, and are shown schematically in Figs. 85A-C.

Transcription reactions were performed using the MEGAshortscript™ system from Ambion, Inc. (Austin, TX), in accordance with the manufacturer's instructions with the exception that a fluorescein labeled ribonucleotide was added. Each DNA sample was assembled in 4 µl of RNase-free dH₂O. Reactions 1-3 each contained 10 pmole of the copy template oligo 150 (SEQ ID NO:123); reaction 2 contained 10 pmole of the promoter oligo 151 (SEQ ID NO:124); sample 3 contained 10 pmole of the 3' tailed promoter oligo 073-065 (SEQ ID NO:125); sample 4 had no added DNA. To each sample, 6 µl of a solution containing 1 µl of 10X Transcription Buffer, 7.5mM each rNTP, 0.125mM fluorescein-12-UTP (Boehringer) and 1 µl T7 MEGAshortscript™ Enzyme Mix was added. The samples were then incubated at 37°C for 1 hour. One microliter of RNase-free DNase I (2U/µl) was added to each sample and the samples were incubated an additional 15 minutes at 37°C. The reactions were then stopped by the addition of 10 µl of a solution of 95% formamide, 5mM Na₂EDTA, with loading dyes. All samples were heated to 95°C for 2 minutes and 4 µl of each sample was resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7M urea, in a buffer containing 45mM Tris-Borate

(pH 8.3), 1.4mM EDTA. The gel was analyzed with a FMBIO II fluorescence image analyzer, and the resulting image is shown in Fig. 93. The RNA produced by successful transcription appears near the middle of the panel, as indicated ("RNA").

5 Examination of the products of transcription shown in lanes 2 and 3 show that the presence of the 3' tail on the full-length promoter has an adverse affect on the efficiency of transcription, but does not shut it off completely. Because the objective of the transcription-based visualization assays of the present invention is to discriminate between uncleaved probe and the shorter products of the invasive cleavage assay (cut probe), these data indicate that production of a full-length promoter in the cleavage reaction would be difficult to resolve
10 from the background created by transcription from promoters containing the uncleaved probe if no other oligonucleotides were included in the assay. Means of suppressing transcription from such a branched promoter are discussed in the Description of the Invention and discussed below in Ex. 43.

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EXAMPLE 41

Examination Of The Influence Of The Position Of The Nick On The Efficiency Of Transcription From Partial And Complete Composite Bacteriophage T7 Promoters

20 In the Description of the Invention, the procedure for testing prospective promoter pieces for suitability in an invasive cleavage-linked assay is described. One aspect of the test is to examine the effect a chosen nick site has on the efficiency of transcription from the final composite promoter. In addition, the individual pieces of nicked promoter are tested for transcription activity in the presence of the full-length un-nicked strand. In this experiment, a
25 comparison on these points is made between a composite promoter having a nick in the non-template strand between nucleotides -11 and -10 relative to the initiation site (+1), and a promoter having a nick on the same strand, but positioned between nucleotides -8 and -7. The figure numbers for the schematic representations of the contents of each reaction are indicated below each lane (e.g., 85A = Fig. 85A). The site where the nick would be in a
30 fully assembled composite promoter using the reaction oligonucleotides is also indicated below each lane ("-11/-10" and "-8/-7").

Transcription reactions were performed using the MEGAshortscript™ system, in accordance with the manufacturer's instructions, but with the exception that a fluorescein

labeled ribonucleotide was added. Each DNA sample was assembled in 4 μ l of RNase-free dH_2O . Reaction 1 had no added DNA. Reactions 2-9 each contained 10 pmole of the copy template oligo 150 (SEQ ID NO:123). Reactions 3 and 4 contained 10 pmole of the -11 "cut" probe (oligo 073-061-01; SEQ ID NO:127) or 20 pmole of the -10 partial promoter oligo 073-061-02 (SEQ ID NO:130), respectively, and reaction 5 contained both. Reactions 6 and 7 contained either the 10 pmole of the -8 "cut" probe (oligo 073-062-01; SEQ ID NO:126) or 20 pmoles of the -7 partial promoter oligo 073-062-02 (SEQ ID NO:129), respectively, and reaction 8 contained them both. Reaction 9 contained 10 pmole of the intact promoter oligo 151 (SEQ ID NO:124).

The transcription reactions were initiated, incubated, terminated and the reaction products were resolved and imaged as described in Ex. 40. The resulting image is shown in Fig. 92. The reaction numbers correspond to the lane numbers above the image. The RNA created by successful transcription appears in the upper third of the image. Comparison to the positive control reaction (rxn. 9) shows that the full-length RNA produced by each of the composite promoters is the same size as that produced in the control reaction, indicated that transcription initiated at the same site in each reaction.

In Fig. 92, lanes 3, 4, and 5 compare transcription from the two species of partially assembled promoters (see schematics in Figs. 86A and B) and the fully assembled composite promoter (Fig. 88B) having a nick between nucleotides -11 and -10 relative to the start of transcription. It can be seen from these data that neither partial promoter (lanes 3 and 4) is able to support transcription of the copy template, but that the composite promoter (lane 5) with this nick site is strongly transcribed. Surprisingly, comparison to the control reaction (lane 9) shows that the presence of a nick at this site (-11/-10) actually enhances transcription. While not limiting the present invention to any particular mechanism, it is believed that the enhancement of transcription is a result of both suppressing the formation of the shorter abortive transcripts and by allowing greater accumulation of the full length product. This result is highly reproducible.

In Fig. 92, lanes 6, 7, and 8 compare transcription a similar set of partial and complete promoters in which the nick is shifted 3 residues closer to the transcription start site. Examination of lane 6 shows that the presence of 3 extra bases on the -8 "cut" probe (compared to the -11 "cut" probe in lane 3) allow this partial promoter to initiate transcription. This indicates that the -8/-7 site would be a poor choice for use in this embodiment of the present invention.

This experiment demonstrates the process for determining the suitable placement of a nick within a promoter assembly to achieve the desired result. Similar tests can easily be designed for testing other nicks within the bacteriophage T7 promoter tested in this example, or for testing suitable nick placement in any desired phage, prokaryotic or eukaryotic promoter.

EXAMPLE 42

Detection Of The Products Of Invader™-Directed Cleavage Through Transcription From A Composite Promoter

The examples described above indicate that a small oligonucleotide can be used to complete assembly of a composite T7 promoter, thereby enabling transcription from that promoter. Earlier examples demonstrate that the invasive cleavage reaction can be used to release specific small oligonucleotide products from longer probe oligonucleotides. In this example it is demonstrated that these two observations can be combined, and that the products of the invasive cleavage reaction can be used to complete a promoter and enable subsequent transcription. The schematic representations of the composite promoters tested in this example are shown in Fig. 88.

Two invasive cleavage reactions were set up, one without (rxn. 1) and one with (rxn. 2) input target DNA. The reactions (1 and 2) comprised 10mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles Invader™ oligo 073-073-02 (SEQ ID NO:134) in a volume of 14 µl. Reaction 2 also included 100 fmoles M13mp18 ssDNA. The samples were placed at 60°C and 6 µl of a solution containing 20 ng of *Mja* FEN-1 and 40mM Mg₂Cl were added to each sample to start the reactions. The samples were incubated at 60°C for 30 minutes and stopped by the addition of 3 µl of 2.5M NaOAc, 83mM Na₂EDTA (pH 8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and then the DNAs were precipitated by the addition of 60 µl of chilled 100% ethanol, and were stored at -20°C for 20 minutes. The pellets were collected by microcentrifugation, washed once with 80% ethanol to remove excess salt, then dried under vacuum. The product of this invasive cleavage reaction is a 12 nt oligonucleotide having the sequence: 5'-CGAAATTAATAC-3' (SEQ ID NO:128), termed the -12 cut probe (same sequence as oligo 073-073-03).

For transcription, the dried samples were each dissolved in 4 µl of a solution containing 1 pmole copy template oligo 150 and 2 pmoles -11 partial promoter oligo 073-073-012 (SEQ ID NO:131). Control samples 3 and 4 each contained 1 pmole of the copy template oligo 150; sample 3 also contained 1 pmole probe oligo 073-067-01 (SEQ ID NO:132) and 2 pmoles -11 partial promoter oligo 073-073-012 (see structure 88A); sample 4 contained 1 pmole -12 "cut" probe oligo 073-073-03 (SEQ ID NO:128) and 2 pmoles -11 partial promoter oligo 073-073-012 (see structure 88B). These are the structures that would be expected to exist in the transcription reactions from the two invasive cleavage reactions described above.

The transcription reactions were initiated, incubated, terminated and the products were resolved and imaged as described in Ex. 40. The resulting image is shown in the right half of Fig. 89 (lanes 6-9). Samples 3 and 4 appear in lanes 6 and 7, respectively, and the reactions 1 and 2 from the invasive cleavage reaction products (indicated by the use of the lower case "i"), appear in lanes 8 and 9, respectively. The number of the Fig. showing the schematic representation of the expected promoter structure in each reaction is indicated above each lane, and the placement of the nick is also indicated. The uppercase letters indicate which structure in the particular figure to examine for each reaction. The lowercase "i" above lanes 8 and 9 indicate that these transcriptions were derived from actual invasive cleavage reactions. These products are compared to the RNA produced in the control reaction in lane 5, the procedure for which is described in Ex. 44. The RNA created by successful transcription appears in the upper third of the panel (indicated by "RNA").

The reaction shown in lane 6 shows no transcription. This demonstrates that a nick between nucleotides -12 and -11 in the on-template strand of the T7 promoter eliminates transcription if the promoter is assembled from uncut probe such as the 3' end of the probe forms a branch within the promoter sequence. This is in contrast to the results seen with the -11/-10 nick examined below. Further, the transcript apparent in lane 7 shows that an unbranched promoter with a nick at the same site (-12/-11) produces the correct RNA, with few abortive initiation products (see lanes 2 and 5 of Fig. 89, described in Ex. 44). The reactions in lanes 8 and 9 demonstrate that the same effect is observed when the invasive cleavage reaction is the sole source of the upstream piece (-12 cut probe) of the T7 promoter. It is worthy of note that the promoter that is transcribed in lane 8 is made complete by the presence of 1 pmole of a synthetic "cut" probe oligo, without any uncut probe in the mixture, while the promoter that is transcribed in lane 9 is completed by the product of an invasive

cleavage reaction that had only 100 fmole of target DNA in it. This reaction also included the residual uncut probe (up to approx. 10 pmoles), which may compete for binding at the same site. Nonetheless, the transcriptions from the invasive cleavage reaction products are only slightly reduced in efficiency, and are just as free of background as is the "no target" sample (lane 8). This example clearly demonstrates that the cleavage products from the invasive cleavage reaction can be used in combination with a partial promoter oligo to promote the production of RNA, without background transcription generated by the presence of the uncut probe. This RNA product is clearly dependent on the presence of the target material in the invasive cleavage reaction.

EXAMPLE 43

Shutting Down Transcription From A "Leaky" Branched T7 Composite Promoter Through The Use Of A Downstream Partial Promoter Oligonucleotide Having A 5' Tail

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The previous example demonstrated that placement of a nick in the non-template strand of a bacteriophage T7 promoter between the -12 and -11 nucleotides, relative to the transcription start site, prevents transcription of the branched promoter while allowing transcription when the composite promoter is assembled using the cut probe. When the nick is placed in other locations in the T7 promoter, transcription may be initiated from either promoter, although it is usually less efficient from the branched promoter. This example demonstrates that the addition of a 5' tail that can base pair to the uncut probe (Fig. 90A) to the downstream partial promoter piece effectively blocks transcription from that promoter, but does not prevent transcription when a cut probe completes the promoter (Fig. 90B).

25

Two invasive cleavage reactions were set up, one without (rxn. 7) and one with (rxn. 8) input target DNA. The reactions (7 and 8) comprised 10mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles Invader™ oligo 073-067-02 (SEQ ID NO:133) in a volume of 14 µl. Reaction 8 also included 100 fmole M13mp18 ssDNA. The samples were placed at 60°C and 6 µl of a solution containing 20 ng of *Mja* FEN-1 and 40mM Mg₂Cl were added to each sample to start the reactions. The samples were incubated at 60°C for 30 minutes and then stopped by the addition of 3 µl of 2.5M NaOAc, 83mM Na₂EDTA (pH.8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and the DNAs were precipitated, washed and dried as described

30

in Ex. 42. The product of this invasive cleavage reaction is 13 nt oligonucleotide sequence, 5'-CGAAATTAATACG-3' (SEQ ID NO:127), termed the -11 cut probe (same sequence as oligo 073-061-01 which is referred to as the -11 "cut" probe to indicate it was not generated in an invasive cleavage reaction).

5 In the transcription reactions, all of the DNAs were dissolved in 4 μ l of RNase-free dH₂O. Sample 1 had no added DNA, samples 2-8 contained 1 pmole of the copy template oligo 150 (SEQ ID NO:123). In addition, sample 3 contained 1 pmole of -11 "cut" probe oligo 073-061-01 (SEQ ID NO:127) and 2 pmoles of -10 partial promoter oligo 073-061-02 (SEQ ID NO:130). sample 4 contained 1 pmole of probe oligo 073-067-01 and 2 pmoles of -10 partial promoter oligo 073-061-02. Control sample 5 contained 1 pmole of probe oligo 073-067-01 and 2 pmoles of partial promoter w/5' tail oligo 073-074 (5'-
10 TACTGACTCACTATAGGGTCTTCTATGGAGGTC-3' (SEQ ID NO:146) (*see* structure in Fig. 90A) and sample 6 contained 1 pmole of -11 "cut" probe oligo 073-061-01 and 2 pmoles of partial promoter w/5' tail oligo 073-074 (*see* structure in Fig. 90B). These are the
15 structures (*i.e.*, 90A and 90B) that would be expected to exist in the transcription reactions from the two invasive cleavage reactions described above.

The dried samples 7 and 8 from the invasive cleavage (above) were each dissolved in 4 μ l of dH₂O containing 1 pmole copy template oligo 150 and 2 pmoles partial promoter w/5' tail oligo 073-074. The transcription reactions were initiated, incubated, terminated and
20 the reaction products were resolved and imaged as described in Ex. 40. The resulting image is shown in Fig. 91.

In Fig. 91 the lane numbers correspond to the sample numbers; the number of the figure showing the schematic representation of the expected promoter structure in each reaction is indicated above each lane ("88" and "90"), and the placement of the nick is also
25 indicated ("-11/-10"). The upper-case letters indicate which structure in the particular figure to examine for each reaction. The lower case "i" above lanes 7 and 8 indicates that these transcriptions were derived from actual invasive cleavage reactions. The RNA created by successful transcription appears in the upper third of the panel, as indicated ("RNA").

The control reactions in lanes 1 and 2, having either no DNA or having the only the
30 copy template, produced no RNA as expected. The product in lane 4 demonstrates that the branched T7 promoter with a nick in the non-template strand between nucleotides -11 and -10 can support transcription, albeit not as efficiently as the un-branched promoter with the nick at the same site (lane 3). Examination of lane 5 shows that the use of a partial promoter

oligonucleotide with a short 5' tail that can basepair to the uncut probe as depicted in Fig. 90A, effectively suppresses this transcription but allows transcription when the probe does not have a 3' tail (lane 6: schematic Fig. 90B). The reactions in lanes 7 and 8 demonstrate that the same effect as observed when the invasive cleavage reaction is the sole source of the upstream piece (-11 cut probe, SEQ ID NO:127) of the T7 promoter. It is worthy of note that the promoter that is transcribed in sample 6 is made complete by the presence of 1 pmole of a synthetic "cut probe", without any uncut probe in the mixture, while the promoter that is transcribed in sample 8 is completed by the product of an invasive cleavage reaction that had only 100 fmole of target DNA in it. This reaction also included the residual uncut probe (up to approximately 19 pmoles), which may compete for binding at the same site. Nonetheless, the transcriptions from the invasive cleavage reaction products are just as strong and just as free of background in the "no target" samples.

This example clearly demonstrates that the cleavage products from the invasive cleavage reaction can be used in combination with a partial promoter oligonucleotide having a 5' tail to promote the production of RNA, without background transcription generated by the uncut probe. This RNA product is clearly dependent on the presence of the target material in the invasive cleavage reaction.

20

EXAMPLE 44

Creation Of A Complete Bacteriophage T7 Promoter By DNA Polymerase-Mediated Extension Of A Cut Probe Comprising A Partial T7 Promoter

As demonstrated in the examples above, transcription cannot occur from the T7 promoter unless a complete promoter region is present. In the above examples, a complete promoter containing a nick in one strand was created by annealing a cut probe generated from an invasive cleavage reaction to a copy template which was annealed to a partial promoter oligo. An alternative means of creating a complete promoter in a manner dependent upon detection of a target sequence in an invasive cleavage reaction is to anneal the cut probe to a copy template devoid of a partial promoter oligo. The 3'-OH present at the end of the annealed cut probe is then extended by a DNA polymerase to create a complete and un-nicked promoter which is transcription-competent.

30

In this example the promoter was made complete through the use of primer extension, rather than by the co-hybridization of another oligonucleotide. The reaction steps are diagrammed schematically in Fig. 87. Two invasive cleavage reactions were set up, one without (rxn. 1) and one with (rxn. 2) input target DNA. The reactions (1 and 2) comprised
5 10mM MOPS (pH 7.5), 0.05% Tween-20, 0.05% NP-40 and 20 pmoles probe oligo 073-067-01 (SEQ ID NO:132) and 10 pmoles Invader™ oligo 073-073-02 (SEQ ID NO:134) in a volume of 14 µl. Reaction 2 also included 100 fmoles M13mp18 ssDNA. The samples were placed at 60°C and 6 µl of a solution containing 20ng of *Mja* FEN-1 and 40mM Mg₂Cl were added to each sample to start the reactions. The samples were incubated at 60°C for 30
10 minutes and stopped by the addition of 3 µl of 2.5M NaOAc, 83mM Na₂EDTA (pH 8.0). Each sample was transferred to a 1.5 ml microcentrifuge tube and then the DNAs were precipitated, washed and dried as described in Ex. 42. The product of this invasive cleavage reaction is the 12 nt oligonucleotide sequence: 5'-CGAAATTAATAC-3' (SEQ ID NO:128), termed the -12 cut probe (same sequence as oligo 073-073-03 which is referred to as the -12
15 "cut" probe to indicate it was not generated in an invasive cleavage reaction).

To allow extension of these products using a template-dependent DNA polymerase, a 20 µl solution containing 20mM Tris-HCl (pH 8.5), 1.5mM Mg₂Cl, 50mM KCl, 0.05% Tween-20, 0.05% NP-40, 25µM each dNTP, 0.25 units *Taq* DNA polymerase (Boehringer) and 2 µM copy template oligo 150 (SEQ ID NO:123) was added to each of the dried
20 cleavage samples. The samples were incubated at 30°C for 1 hr. The primer extension reactions were stopped by the addition of 3 µl of 2.5M NaOAc with 83mM Na₂EDTA (pH 8.0)/sample. Each sample was transferred to a 1.5 ml microcentrifuge tube and the DNAs were precipitated, washed and dried as described in Ex. 42.

Samples 1 and 2 were then dissolved in 4 µl RNase-free dH₂O. Samples 3, 4 and 5
25 are control reactions: sample 3 was 4 µl of RNase-free dH₂O without added DNA. sample 4 contained 1 pmole of the copy template oligo 150 (SEQ ID NO:123) in 4 µl of RNase-free dH₂O, and sample 5 contained 1 pmole of the same copy template and 1 pmole of the complete promoter oligo 151 (SEQ ID NO:124) in RNase-free dH₂O.

Transcription reactions were performed using the MEGAshortscript™ system, in
30 accordance with the manufacturer's instructions, but with the addition of a fluorescein labeled ribonucleotide. To each sample, 6 µl of a solution containing 1 µl of 10X Transcription Buffer, 7.5mM each rNTP, 0.125mM fluorescein-12-UTP (Boehringer) and 1 µl T7 MEGAshortscript™ Enzyme Mix was added. The samples were incubated at 37°C for 1

hour. One μ l of RNase-free DNase I (2U/ μ l) was added to each sample and they were incubated an additional 15 minutes at 37°C. The reactions were stopped by the addition of 10 μ l of a solution of 95% formamide, 5mM NaEDTA, with loading dyes. All samples were heated to 95°C for 2 minutes and four μ l of each sample was resolved by electrophoresis through a 20% denaturing acrylamide gel (19:1 cross-linked) with 7 M urea, in a buffer containing 45 mM Tris-Borate (pH 8.3), 1.4mM EDTA. The results were imaged using the Molecular Dynamics Fluoroimager 595, with excitation at 488 nm and, emission detected at 530 nm.

The resulting image is shown in lanes 1 through 5 of Fig. 89; the lane numbers correspond to the sample numbers. The figure numbers corresponding to the schematic representations of the promoters transcribed in each reaction as indicated above the lanes. The RNA product from successful transcription appears in the upper third of the panel, as indicated ("RNA"). Unincorporated labeled nucleotide appears as a dense signal near the bottom ("NTPs"). Short transcription products caused by aborted initiation events [Milligan and Uhlenbeck (1989) Methods Enzymol. 180:51] appear as bands just above the free nucleotide in the lanes showing active transcription (*i.e.*, lanes 2 and 5).

It can clearly be seen from the data in lanes 1 and 2 that the transcription is dependent on the presence of the target material in the invasive cleavage reaction. It is shown elsewhere (see lane 3, Fig. 92) that the product of the cleavage reaction is not in itself sufficient to allow transcription from the copy template. Thus, the action of the DNA polymerase in extending the hybridized cut probe across the promoter is a necessary step in enabling the transcription in this embodiment. These data clearly demonstrate that both template-dependent extension by DNA polymerase, and extension followed by transcription are suitable methods of visualizing the products of the invasive cleavage assay. As discussed in the Description of the Invention, the products of thermal breakdown that possess 3' terminal phosphates would not be extended, and would thus be precluded from contributing to background transcription.

From the above it is clear that the invention provides reagents and methods to permit the detection and characterization of nucleic acid sequences and variations in nucleic acid sequences. The Invader™-directed cleavage reaction of the present invention provides an ideal direct detection method that combines the advantages of the direct detection assays (*e.g.*,
5 easy quantification and minimal risk of carry-over contamination) with the specificity provided by a dual or tri oligonucleotide hybridization assay.

All publications and patents mentioned in the above specification are herein incorporated by reference. Various modifications and variations of the described method and system of the invention will be apparent to those skilled in the art without departing from the
10 scope and spirit of the invention. Although the invention has been described in connection with specific preferred embodiments, it should be understood that the invention as claimed should not be unduly limited to such specific embodiments. Indeed, various modifications of the described modes for carrying out the invention which are obvious to those skilled in molecular biology or related fields are intended to be within the scope of the following
15 claims.

SEQUENCE LISTING

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 - (D) SOFTWARE: PatentIn Release #1.0, Version #1.30
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 - (A) APPLICATION NUMBER: US 08/756,386
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(2) INFORMATION FOR SEQ ID NO:1:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 2506 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

ATGAGGGGGA TGCTGCCCCT CTTTGAGCCC AAGGGCCGGG TCCTCCTGGT GGACGGCCAC	60
CACCTGGCCT ACCGCACCTT CCACGCCCTG AAGGGCCTCA CCACCAGCCG GGGGAGCCG	120
GTGCAGGCGG TCTACGGCTT CGCCAAGAGC CTCCTCAAGG CCCTCAAGGA GGACGGGGAC	180
GCGGTGATCG TGGTCTTTGA CGCCAAGGCC CCCTCCTTCC GCCACGAGGC CTACGGGGGG	240
TACAAGGCGG GCCGGGCCCC CACGCCGGAG GACTTTCCCC GGCAACTCGC CCTCATCAAG	300
GAGCTGGTGG ACCTCCTGGG GCTGGCGCGC CTCGAGGTCC CGGGCTACGA GGCGGACGAC	360
GTCCTGGCCA GCCTGGCCAA GAAGGCGGAA AAGGAGGGCT ACGAGGTCCG CATCCTCACC	420
GCCGACAAAG ACCTTTACCA GCTCCTTTCC GACCGCATCC ACGTCCTCCA CCCCAGGGGG	480
TACCTCATCA CCCCAGCCTG GCTTTGGGAA AAGTACGGCC TGAGGCCCGA CCAGTGGGCC	540
GACTACCGGG CCCTGACCGG GGACGAGTCC GACAACCTTC CCGGGGTCAA GGCATCGGG	600
GAGAAGACGG CGAGGAAGCT TCTGGAGGAG TGGGGGAGCC TGAAGCCCT CCTCAAGAAC	660
CTGGACCGGC TGAAGCCCGC CATCCGGGAG AAGATCCTGG CCCACATGGA CGATCTGAAG	720
CTCTCCTGGG ACCTGGCCAA GGTGCGCACC GACCTGCCCC TGGAGGTGGA CTTGCGCCAA	780
AGGCGGGAGC CCGACCGGGA GAGGCTTAGG GCCTTTCTGG AGAGGCTTGA GTTTGGCAGC	840
CTCTCCACG AGTTTCGGCCT TCTGGAAAGC CCCAAGGCCC TGGAGGAGGC CCCCTGGCCC	900
CCGCCGAAG GGGCCTTCGT GGGCTTTGTG CTTTCCCGCA AGGAGCCCAT GTGGGCCGAT	960
CTTCTGGCCC TGGCCGCCG CAGGGGGGGC CGGGTCCACC GGGCCCCCGA GCCTTATAAA	1020
GCCCTCAGGG ACCTGAAGGA GGC GCGGGGG CTTCTCGCCA AAGACCTGAG CGTTCTGGCC	1080
CTGAGGGAAG GCCTTGGCCT CCCGCCGGC GACGACCCCA TGCTCCTCGC CTACCTCCTG	1140
GACCCTTCCA ACACCACCCC CGAGGGGGTG GCCCGCGCT ACGGCGGGGA GTGGACGGAG	1200
GAGGCGGGGG AGCGGGCCGC CCTTTCCGAG AGGCTCTTCG CCAACCTGTG GGGGAGGCTT	1260
GAGGGGGAGG AGAGGCTCCT TTGGCTTTAC CGGGAGGTGG AGAGGCCCTT TTCCGCTGTC	1320
CTGGCCCACA TGGAGGCCAC GGGGGTGCGC CTGGACGTGG CCTATCTCAG GGCTTGCTCC	1380
CTGGAGGTGG CCGAGGAGAT CGCCCGCCTC GAGGCCGAGG TCTTCGCCTT GGCCGGCCAC	1440
CCCTTCAACC TCAACTCCCG GGACCAGCTG GAAAGGGTCC TCTTTGACGA GCTAGGGCTT	1500
CCCGCCATCG GCAAGACGGA GAAGACCGG AAGCGCTCCA CCAGCGCCGC CGTCTGGAG	1560
GCCCTCCGCG AGGCCACCC CATCGTGGAG AAGATCCTGC AGTACCGGA GCTACCAAG	1620
CTGAAGAGCA CCTACATTGA CCCCTTGCCG GACCTCATCC ACCCCAGGAC GGGCCGCTC	1680

CACACCCGCT TCAACCAGAC GGCCACGGCC ACGGGCAGGC TAAGTAGCTC CGATCCCAAC	1740
CTCCAGAACA TCCCCGTCCT CACCCCGCTT GGGCAGAGGA TCCGCCGGGC CTTTCATCGCC	1800
GAGGAGGGGT GGCTATTGGT GGCCCTGGAC TATAGCCAGA TAGAGCTCAG GGTGCTGGCC	1860
CACCTCTCCG GCGACGAGAA CCTGATCCGG GTCTTCCAGG AGGGGCGGGA CATCCACACG	1920
GAGACCGCCA GCTGGATGTT CGGCGTCCCC CGGGAGGCCG TGGACCCCTT GATGCGCCGG	1980
GCGGCCAAGA CCATCAACTT CGGGGTCTCT TACGGCATGT CGGCCACCG CCTCTCCCAG	2040
GAGCTAGCCA TCCCTTACGA GGAGGCCAG GCCTTCATTG AGCGCTACTT TCAGAGCTTC	2100
CCCAAGGTGC GGGCCTGGAT TGAGAAGACC CTGGAGGAGG GCAGGAGGCG GGGGTACGTG	2160
GAGACCTCT TCGGCCGCGG CCGCTACGTG CCAGACCTAG AGGCCCGGGT GAAGAGCGTG	2220
CGGGAGGCGG CCGAGCGCAT GGCCTTCAAC ATGCCCGTCC AGGGCACC GC	2280
ATGAAGCTGG CTATGGTGA GCTCTTCCCC AGGTGGAGG AAATGGGGGC CAGGATGCTC	2340
CTTCAGGTCC ACGACGAGCT GGTCTCGAG GCCCCAAAAG AGAGGGCGGA GGCCGTGGCC	2400
CGGCTGGCCA AGGAGGTCAT GGAGGGGGTG TATCCCCTGG CCGTGCCCTT GGAGGTGGAG	2460
GTGGGGATAG GGGAGGACTG GCTCTCCGCC AAGGAGTGAT ACCACC	2506

(2) INFORMATION FOR SEQ ID NO:2:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 2496 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

ATGGCGATGC TTCCCTCTT TGAGCCCAA GGCCGCGTGC TCCTGGTGA CGGCCACCAC	60
CTGGCCTACC GCACCTTCTT TGCCCTCAAG GGCTCACCA CCAGCCGCGG CGAACCCGTT	120
CAGGCGGTCT ACGGCTTCGC CAAAAGCCTC CTCAAGGCC TGAAGGAGGA CGGGGACGTG	180
GTGGTGGTGG TCTTTGACGC CAAGGCCCC TCCTTCCGCC ACGAGGCCTA CGAGGCCTAC	240
AAGGCGGGCC GGGCCCCAC CCCGGAGGAC TTTCCCCGGC AGCTGGCCCT CATCAAGGAG	300
TTGGTGGACC TCCTAGGCCT TGTGCGGCTG GAGGTTCCTG GCTTTGAGGC GGACGACGTG	360
CTGGCCACCC TGGCCAAGCG GCGGAAAAG GAGGGGTACG AGGTGCGCAT CCTCACTGCC	420
GACCGCGACC TCTACCAGCT CCTTTCGGAG CGCATCGCCA TCCTCCACCC TGAGGGGTAC	480
CTGATCACCC CGGCGTGGCT TTACGAGAAG TACGGCCTGC GCCCGAGCA GTGGGTGGAC	540
TACCGGGCCC TGGCGGGGA CCCCTCGGAT AACATCCCCG GGTGAAGGG CATCGGGGAG	600
AAGACCGCCC AGAGGCTCAT CCGCGAGTGG GGGAGCCTGG AAAACCTCTT CCAGCACCTG	660
GACCAGGTGA AGCCCTCCTT GCGGGAGAAG CTCCAGGCGG GCATGGAGGC CCTGGCCCTT	720
TCCCGGAAGC TTCCCAGGT GCACACTGAC CTGCCCTGG AGGTGGACTT CGGGAGGCGC	780
CGCACACCCA ACCTGGAGGG TCTGCGGGCT TTTTGGAGC GGTGGAGTT TGAAGCCTC	840

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CTCCACGAGT TCGGCCTCCT GGAGGGGCGG AAGGCGGCAG AGGAGGCCCC CTGGCCCCCT      900
CCGGAAGGGG CTTTTTGGG CTTTTCCTTT TCCCGTCCCG AGCCCATGTG GGCCGAGCTT      960
CTGGCCCTGG CTGGGGCGTG GGAGGGGCGC CTCCATCGGG CACAAGACCC CCTTAGGGGC     1020
CTGAGGGACC TTAAGGGGGT GCGGGGAATC CTGGCCAAGG ACCTGGCGGT TTTGGCCCTG     1080
CGGGAGGGCC TGGACCTCTT CCCAGAGGAC GACCCCATGC TCCTGGCCTA CTTCTGGAC      1140
CCCTCCAACA CCACCCCTGA GGGGGTGGCC CGGCGTTACG GGGGGGAGTG GACGGAGGAT      1200
GCGGGGGAGA GGGCCCTCCT GGCCGAGCGC CTCTTCCAGA CCCTAAAGGA GCGCCTTAAG     1260
GGAGAAGAAC GCCTGCTTTG GCTTTACGAG GAGGTGGAGA AGCCGCTTTC CCGGGTGTG      1320
GCCCCGATGG AGGCCACGGG GGTCCGGCTG GACGTGGCCT ACCTCCAGGC CCTCTCCCTG     1380
GAGGTGGAGG CGGAGGTGCG CCAGCTGGAG GAGGAGGTCT TCCGCTGGC CGGCCACCCC     1440
TTCAACCTCA ACTCCCGCGA CCAGCTGGAG CGGGTGTCTT TTGACGAGCT GGGCCTGCCT     1500
GCCATCGGCA AGACGGAGAA GACGGGGAAA CGCTCCACCA GCGCTGCCGT GCTGGAGGCC     1560
CTGCGAGAGG CCCACCCCAT CGTGGACCGC ATCCTGCAGT ACCGGGAGCT CACCAAGCTC     1620
AAGAACACCT ACATAGACCC CCTGCCCGCC CTGGTCCACC CCAAGACCGG CCGGCTCCAC     1680
ACCCGCTTCA ACCAGACGGC CACCGCCACG GGCAGGCTTT CCAGCTCCGA CCCCACCTG      1740
CAGAACATCC CCGTGCGCAC CCCTCTGGG CAGCGCATCC GCCGAGCCTT CGTGGCCGAG     1800
GAGGGCTGGG TGCTGGTGGT CTTGGACTAC AGCCAGATTG AGCTTCGGGT CCTGGCCAC      1860
CTCTCCGGG ACGAGAACCT GATCCGGGTC TTTCAGGAGG GGAGGGACAT CCACACCCAG     1920
ACCGCCAGCT GGATGTTTCG CGTTTCCCCC GAAGGGGTAG ACCCTCTGAT GCGCCGGGCG     1980
GCCAAGACCA TCAACTTCGG GGTGCTCTAC GGCATGTCCG CCCACCGCCT CTCCGGGGAG     2040
CTTTCCATCC CCTACGAGGA GGCGGTGGCC TTCAATTGAGC GCTACTTCCA GAGCTACCCC     2100
AAGGTGCGGG CCTGGATTGA GGGGACCCTC GAGGAGGGCC GCCGGCGGGG GTATGTGGAG     2160
ACCTCTTCG GCCGCCGGCG CTATGTGCCC GACCTCAACG CCCGGGTGAA GAGCGTGCGC     2220
GAGGCGGCGG AGCGCATGGC CTTCAACATG CCGGTCCAGG GCACCGCCGC CGACCTCATG     2280
AAGCTGGCCA TGGTGCGGCT TTTCCCCCGG CTTCAGGAAC TGGGGGCGAG GATGCTTTTG     2340
CAGGTGCACG ACGAGCTGGT CCTCGAGGCC CCCAAGGACC GGGCGGAGAG GGTAGCCGCT     2400
TTGGCCAAGG AGGTCATGGA GGGGTCTGG CCCCTGCAGG TGCCCCCTGA GGTGGAGGTG     2460
GGCCTGGGGG AGGACTGGCT CTCCGCCAAG GAGTAG      2496

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(2) INFORMATION FOR SEQ ID NO:3:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 2504 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

ATGGAGGCGA TGCTTCGCT CTTTGAACCC AAAGGCCGGG TCCTCCTGGT GGACGGCCAC	60
CACCTGGCCT ACCGCACCTT CTTCGCCCTG AAGGGCCTCA CCACGAGCCG GGGCGAACCG	120
GTGCAGGCGG TCTACGGCTT CGCCAAGAGC CTCCTCAAGG CCCTGAAGGA GGACGGGTAC	180
AAGGCCGTCT TCGTGGTCTT TGACGCCAAG GCCCCCTCCT TCCGCCACGA GGCCTACGAG	240
GCCTACAAGG CGGGGAGGGC CCCGACCCCC GAGGACTTCC CCCGGCAGCT CGCCCTCATC	300
AAGGAGCTGG TGGACCTCCT GGGGTTTACC CGCCTCGAGG TCCCCGGCTA CGAGGCGGAC	360
GACGTTCTCG CCACCTGGC CAAGAAGGCG GAAAAGGAGG GGTACGAGGT GCGCATCCTC	420
ACCGCCGACC GCGACCTCTA CCAACTCGTC TCCGACCGCG TCGCCGTCCT CCACCCGAG	480
GGCCACCTCA TCACCCGGA GTGGCTTTGG GAGAAGTACG GCCTCAGGCC GGAGCAGTGG	540
GTGGACTTCC GCGCCCTCGT GGGGGACCCC TCCGACAACC TCCCCGGGT CAAGGGCATC	600
GGGGAGAAGA CCGCCCTCAA GCTCCTCAAG GAGTGGGGA GCCTGGAAAA CCTCCTCAAG	660
AACCTGGACC GGGTAAAGCC AGAAAACGTC CGGGAGAAGA TCAAGGCCCA CCTGGAAGAC	720
CTCAGGCTCT CCTTGAGCT CTCCCGGGTG CGCACCAGC TCCCCCTGGA GGTGGACCTC	780
GCCCAGGGGC GGGAGCCCGA CCGGAGGGG CTTAGGGCCT TCCTGGAGAG GCTGGAGTTC	840
GGCAGCCTCC TCCACGAGTT CGGCCTCCTG GAGGCCCCG CCCCCCTGGA GGAGGCCCCC	900
TGGCCCCCG CGGAAGGGC CTTCGTGGGC TTCGTCCTCT CCCGCCCCGA GCCCATGTGG	960
GCGGAGCTTA AAGCCCTGGC CGCCTGCAGG GACGGCCGGG TGACCCGGC AGCAGACCCC	1020
TTGGCGGGG TAAAGGACCT CAAGGAGGTC CGGGGCCTCC TCGCCAAGGA CCTCGCCGTC	1080
TTGGCCTCGA GGGAGGGGCT AGACCTCGTG CCCGGGGACG ACCCATGCT CCTCGCCTAC	1140
CTCCTGGACC CCTCCAACAC CACCCCGAG GGGGTGGCG GCGCTACGG GGGGGAGTGG	1200
ACGGAGGACG CCGCCACCG GGCCTCCTC TCGAGAGGC TCCATCGGA CCTCCTTAAG	1260
CGCCTCGAGG GGGAGGAGAA GCTCCTTTGG CTCTACCAG AGGTGGAAAA GCCCCTCTCC	1320
CGGTCTCTGG CCCACATGGA GGCCACCGG GTACGGCTGG ACGTGGCCTA CCTTCAGGCC	1380
CTTTCCCTGG AGCTTGCGGA GGAGATCCG CGCCTCGAGG AGGAGGTCTT CGCTTGGCG	1440
GGCCACCCCT TCAACCTCAA CTCCCGGAC CAGCTGGAAA GGGTGCTCTT TGACGAGCTT	1500
AGGCTTCCCG CTTTGGGGA GACGCAAAAG ACAGGCAAGC GCTCCACCAG CGCCGCGGTG	1560
CTGGAGGCCC TACGGGAGGC CCACCCATC GTGGAGAAGA TCCTCCAGCA CCGGAGCTC	1620
ACCAAGCTCA AGAACACCTA CGTGGACCCC CTCCAAGCC TCGTCCACCC GAGGACGGGC	1680
CGCCTCCACA CCCGCTTCAA CCAGACGGC ACGGCCACGG GGAGGCTTAG TAGCTCCGAC	1740
CCCAACCTGC AGAACATCCC CGTCCGACC CCCTTGGGCC AGAGGATCCG CCGGGCCTTC	1800
GTGGCCGAGG CGGGTTGGGC GTTGGTGGCC CTGGACTATA GCCAGATAGA GCTCCGCGTC	1860
CTCGCCACC TCTCCGGGA CGAAAACCTG ATCAGGGTCT TCCAGGAGG GAAGGACATC	1920
CACACCCAGA CCGCAAGCTG GATGTTGGC GTCCCCCGG AGGCCGTGGA CCCCTGATG	1980


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CGCCGGGCGG CCAAGACGGT GAACTTCGGC GTCCTCTACG GCATGTCCGC CCATAGGCTC      2040
TCCCAGGAGC TTGCCATCCC CTACGAGGAG GCGGTGGCCT TTATAGAGGC TACTTCCAAA      2100
GCTTCCCCAA GGTGCGGGCC TGGATAGAAA AGACCCTGGA GGAGGGGAGG AAGCGGGGCT      2160
ACGTGGA AAC CCTCTTCGGA AGAAGGCGCT ACGTGCCCGA CCTCAACGCC CGGGTGAAGA      2220
GCGTCAGGGA GGCCGCGGAG CGCATGGCCT TCAACATGCC CGTCCAGGCG ACCGCCGCCG      2280
ACCTCATGAA GCTCGCCATG GTGAAGCTCT TCCCCGCGCT CCGGGAGATG GGGGCCCGCA      2340
TGCTCTCCA GGTCCACGAC GAGCTCCTCC TGGAGGCCCC CCAAGCGCGG GCCGAGGAGG      2400
TGGCGGCTTT GGCCAAGGAG GCCATGGAGA AGGCCTATCC CCTCGCCGTG CCCCTGGAGG      2460
TGGAGGTGGG GATGGGGGAG GACTGGCTTT CCGCCAAGGG TTAG                          2504

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(2) INFORMATION FOR SEQ ID NO:4:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 832 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

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Met Arg Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1             5             10             15
Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly
 20             25             30
Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35             40             45
Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val
 50             55             60
Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly
 65             70             75             80
Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
 85             90             95
Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu Glu
 100            105            110
Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys Lys
 115            120            125
Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys Asp
 130            135            140
Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu Gly
 145            150            155            160
Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165            170            175
Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp Asn
 180            185            190

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Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu Leu
 195 200 205
 Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg Leu
 210 215 220
 Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu Lys
 225 230 235 240
 Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala Phe
 260 265 270
 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala Asp
 305 310 315 320
 Leu Leu Ala Leu Ala Ala Arg Gly Gly Arg Val His Arg Ala Pro
 325 330 335
 Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu Leu
 340 345 350
 Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu Pro
 355 360 365
 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn Leu
 405 410 415
 Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg Glu
 420 425 430
 Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495
 Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser Thr
 530 535 540

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Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg Leu
545                      550                      555                      560

His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
                    565                      570                      575

Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
                    580                      585                      590

Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val Ala
595                      600                      605

Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
610                      615                      620

Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
625                      630                      635                      640

Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp Pro
645                      650                      655

Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
660                      665                      670

Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
675                      680                      685

Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
690                      695                      700

Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
705                      710                      715                      720

Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala Arg
725                      730                      735

Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
740                      745                      750

Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
755                      760                      765

Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val His
770                      775                      780

Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val Ala
785                      790                      795                      800

Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
805                      810                      815

Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys Glu
820                      825                      830

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(2) INFORMATION FOR SEQ ID NO:5:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 831 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

Met Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu Val
 1 5 10 15
 Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly Leu
 20 25 30
 Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala Lys
 35 40 45
 Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Val Val Val Val Val
 50 55 60
 Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu Ala Tyr
 65 70 75 80
 Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu Ala
 85 90 95
 Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Val Arg Leu Glu Val
 100 105 110
 Pro Gly Phe Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys Arg Ala
 115 120 125
 Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg Asp Leu
 130 135 140
 Tyr Gln Leu Leu Ser Glu Arg Ile Ala Ile Leu His Pro Glu Gly Tyr
 145 150 155 160
 Leu Ile Thr Pro Ala Trp Leu Tyr Glu Lys Tyr Gly Leu Arg Pro Glu
 165 170 175
 Gln Trp Val Asp Tyr Arg Ala Leu Ala Gly Asp Pro Ser Asp Asn Ile
 180 185 190
 Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Gln Arg Leu Ile Arg
 195 200 205
 Glu Trp Gly Ser Leu Glu Asn Leu Phe Gln His Leu Asp Gln Val Lys
 210 215 220
 Pro Ser Leu Arg Glu Lys Leu Gln Ala Gly Met Glu Ala Leu Ala Leu
 225 230 235 240
 Ser Arg Lys Leu Ser Gln Val His Thr Asp Leu Pro Leu Glu Val Asp
 245 250 255
 Phe Gly Arg Arg Arg Thr Pro Asn Leu Glu Gly Leu Arg Ala Phe Leu
 260 265 270
 Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu Glu
 275 280 285
 Gly Pro Lys Ala Ala Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly Ala
 290 295 300
 Phe Leu Gly Phe Ser Phe Ser Arg Pro Glu Pro Met Trp Ala Glu Leu
 305 310 315 320
 Leu Ala Leu Ala Gly Ala Trp Glu Gly Arg Leu His Arg Ala Gln Asp
 325 330 335
 Pro Leu Arg Gly Leu Arg Asp Leu Lys Gly Val Arg Gly Ile Leu Ala
 340 345 350

Lys Asp Leu Ala Val Leu Ala Leu Arg Glu Gly Leu Asp Leu Phe Pro
 355 360 365
 Glu Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn Thr
 370 375 380
 Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu Asp
 385 390 395 400
 Ala Gly Glu Arg Ala Leu Leu Ala Glu Arg Leu Phe Gln Thr Leu Lys
 405 410 415
 Glu Arg Leu Lys Gly Glu Glu Arg Leu Leu Trp Leu Tyr Glu Glu Val
 420 425 430
 Glu Lys Pro Leu Ser Arg Val Leu Ala Arg Met Glu Ala Thr Gly Val
 435 440 445
 Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu Val Glu Ala
 450 455 460
 Glu Val Arg Gln Leu Glu Glu Glu Val Phe Arg Leu Ala Gly His Pro
 465 470 475 480
 Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp Glu
 485 490 495
 Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg Ser
 500 505 510
 Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile Val
 515 520 525
 Asp Arg Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Asn Thr Tyr
 530 535 540
 Ile Asp Pro Leu Pro Ala Leu Val His Pro Lys Thr Gly Arg Leu His
 545 550 555 560
 Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser Ser
 565 570 575
 Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln Arg
 580 585 590
 Ile Arg Arg Ala Phe Val Ala Glu Glu Gly Trp Val Leu Val Val Leu
 595 600 605
 Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly Asp
 610 615 620
 Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr Gln
 625 630 635 640
 Thr Ala Ser Trp Met Phe Gly Val Ser Pro Glu Gly Val Asp Pro Leu
 645 650 655
 Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly Met
 660 665 670
 Ser Ala His Arg Leu Ser Gly Glu Leu Ser Ile Pro Tyr Glu Glu Ala
 675 680 685
 Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Tyr Pro Lys Val Arg Ala
 690 695 700

Trp Ile Glu Gly Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val Glu
 705 710 715 720
 Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn Ala Arg Val
 725 730 735
 Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro Val
 740 745 750
 Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Arg Leu Phe
 755 760 765
 Pro Arg Leu Gln Glu Leu Gly Ala Arg Met Leu Leu Gln Val His Asp
 770 775 780
 Glu Leu Val Leu Glu Ala Pro Lys Asp Arg Ala Glu Arg Val Ala Ala
 785 790 795 800
 Leu Ala Lys Glu Val Met Glu Gly Val Trp Pro Leu Gln Val Pro Leu
 805 810 815
 Glu Val Glu Val Gly Leu Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

(2) INFORMATION FOR SEQ ID NO:6:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 834 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Met Glu Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1 5 10 15
 Val Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly
 20 25 30
 Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
 35 40 45
 Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Tyr Lys Ala Val Phe
 50 55 60
 Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu
 65 70 75 80
 Ala Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
 85 90 95
 Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Phe Thr Arg Leu
 100 105 110
 Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys
 115 120 125
 Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg
 130 135 140
 Asp Leu Tyr Gln Leu Val Ser Asp Arg Val Ala Val Leu His Pro Glu
 145 150 155 160

Gly His Leu Ile Thr Pro Glu Trp Leu Trp Glu Lys Tyr Gly Leu Arg
 165 170 175
 Pro Glu Gln Trp Val Asp Phe Arg Ala Leu Val Gly Asp Pro Ser Asp
 180 185 190
 Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Leu Lys Leu
 195 200 205
 Leu Lys Glu Trp Gly Ser Leu Glu Asn Leu Leu Lys Asn Leu Asp Arg
 210 215 220
 Val Lys Pro Glu Asn Val Arg Glu Lys Ile Lys Ala His Leu Glu Asp
 225 230 235 240
 Leu Arg Leu Ser Leu Glu Leu Ser Arg Val Arg Thr Asp Leu Pro Leu
 245 250 255
 Glu Val Asp Leu Ala Gln Gly Arg Glu Pro Asp Arg Glu Gly Leu Arg
 260 265 270
 Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly
 275 280 285
 Leu Leu Glu Ala Pro Ala Pro Leu Glu Glu Ala Pro Trp Pro Pro Pro
 290 295 300
 Glu Gly Ala Phe Val Gly Phe Val Leu Ser Arg Pro Glu Pro Met Trp
 305 310 315 320
 Ala Glu Leu Lys Ala Leu Ala Ala Cys Arg Asp Gly Arg Val His Arg
 325 330 335
 Ala Ala Asp Pro Leu Ala Gly Leu Lys Asp Leu Lys Glu Val Arg Gly
 340 345 350
 Leu Leu Ala Lys Asp Leu Ala Val Leu Ala Ser Arg Glu Gly Leu Asp
 355 360 365
 Leu Val Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro
 370 375 380
 Ser Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp
 385 390 395 400
 Thr Glu Asp Ala Ala His Arg Ala Leu Leu Ser Glu Arg Leu His Arg
 405 410 415
 Asn Leu Leu Lys Arg Leu Glu Gly Glu Glu Lys Leu Leu Trp Leu Tyr
 420 425 430
 His Glu Val Glu Lys Pro Leu Ser Arg Val Leu Ala His Met Glu Ala
 435 440 445
 Thr Gly Val Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu
 450 455 460
 Leu Ala Glu Glu Ile Arg Arg Leu Glu Glu Glu Val Phe Arg Leu Ala
 465 470 475 480
 Gly His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu
 485 490 495
 Phe Asp Glu Leu Arg Leu Pro Ala Leu Gly Lys Thr Gln Lys Thr Gly
 500 505 510

Lys Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His
 515 520 525
 Pro Ile Val Glu Lys Ile Leu Gln His Arg Glu Leu Thr Lys Leu Lys
 530 535 540
 Asn Thr Tyr Val Asp Pro Leu Pro Ser Leu Val His Pro Arg Thr Gly
 545 550 555 560
 Arg Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu
 565 570 575
 Ser Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu
 580 585 590
 Gly Gln Arg Ile Arg Arg Ala Phe Val Ala Glu Ala Gly Trp Ala Leu
 595 600 605
 Val Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu
 610 615 620
 Ser Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Lys Asp Ile
 625 630 635 640
 His Thr Gln Thr Ala Ser Trp Met Phe Gly Val Pro Pro Glu Ala Val
 645 650 655
 Asp Pro Leu Met Arg Arg Ala Ala Lys Thr Val Asn Phe Gly Val Leu
 660 665 670
 Tyr Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr
 675 680 685
 Glu Glu Ala Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys
 690 695 700
 Val Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Lys Arg Gly
 705 710 715 720
 Tyr Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn
 725 730 735
 Ala Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn
 740 745 750
 Met Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val
 755 760 765
 Lys Leu Phe Pro Arg Leu Arg Glu Met Gly Ala Arg Met Leu Leu Gln
 770 775 780
 Val His Asp Glu Leu Leu Glu Ala Pro Gln Ala Arg Ala Glu Glu
 785 790 795 800
 Val Ala Ala Leu Ala Lys Glu Ala Met Glu Lys Ala Tyr Pro Leu Ala
 805 810 815
 Val Pro Leu Glu Val Glu Val Gly Met Gly Glu Asp Trp Leu Ser Ala
 820 825 830
 Lys Gly

(2) INFORMATION FOR SEQ ID NO:7:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 2502 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

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ATGNNGGCGA TGCTTCCCCT CTTTGAGCCC AAAGGCCGGG TCCTCCTGGT GGACGGCCAC      60
CACCTGGCCT ACCGCACCTT CTTGCCCTG AAGGGCCTCA CCACCAGCCG GGGCGAACCG      120
GTGCAGGCGG TCTACGGCTT CGCCAAGAGC CTCCTCAAGG CCCTGAAGGA GGACGGGGAC      180
NNGGCGGTGN TCGTGGTCTT TGACGCCAAG GCCCCCTCCT TCCGCCACGA GGCCTACGAG      240
GCCTACAAGG CGGGCCGGGC CCCCACCCCG GAGGACTTTC CCCGGCAGCT CGCCCTCATC      300
AAGGAGCTGG TGGACCTCCT GGGGCTTGG CGCCTCGAGG TCCCCGGCTA CGAGGCGGAC      360
GACGTNCTGG CCACCCTGGC CAAGAAGGCG GAAAAGGAGG GGTACGAGGT GCGCATCCTC      420
ACCGCCGACC GCGACCTCTA CCAGCTCCTT TCCGACCGCA TCGCCGTCCT CCACCCCGAG      480
GGGTACCTCA TCACCCCGGC GTGGCTTTGG GAGAAGTACG GCCTGAGGCC GGAGCAGTGG      540
GTGGACTACC GGGCCCTGGC GGGGGACCCC TCCGACAACC TCCCCGGGT CAAGGGCATC      600
GGGGAGAAGA CCGCCNGAA GCTCCTCNAG GAGTGGGGGA GCCTGGA AAA CCTCCTCAAG      660
AACCTGGACC GGGTGAAGCC CGCCTCCGG GAGAAGATCC AGGCCACAT GGAGACCTG      720
ANGCTCTCCT GGGAGCTNTC CCAGGTGCGC ACCGACCTGC CCCTGGAGGT GGACTTCGCC      780
AAGNGGCGGG AGCCCGACCG GGAGGGGCTT AGGGCCTTTC TGGAGAGGCT GGAGTTTGGC      840
AGCCTCCTCC ACGAGTTCGG CTCCTGGAG GGGCCCAAG CCCTGGAGGA GGCCCCCTGG      900
CCCCCGCCGG AAGGGGCTT CGTGGGCTT GTCCTTTCC GCCCCGAGCC CATGTGGGCC      960
GAGCTTCTGG CCCTGGCCGC CGCCAGGGAG GGC CGGTCC ACCGGGCACC AGACCCCTTT      1020
ANGGGCCTNA GGGACCTNAA GGAGGTGCGG GGNCTCCTCG CCAAGGACCT GGCCGTTTTG      1080
GCCCTGAGGG AGGGCCTNGA CCTCNTGCCC GGGGACGACC CCATGCTCCT CGCCTACCTC      1140
CTGGACCCCT CCAACACCAC CCCCAGGGG GTGGCCCGGC GCTACGGGGG GGAGTGGACG      1200
GAGGANGCGG GGGAGCGGCG CCTCCTNTCC GAGAGGCTCT TCCNGAACCT NNNGCAGCGC      1260
CTTGAGGGGG AGGAGAGGCT CCTTTGGCTT TACCAGGAGG TGGAGAAGCC CCTTTCCCGG      1320
GTCTTGGCCC ACATGGAGGC CACGGGGGTN CGGCTGGACG TGGCCTACCT CCAGGCCCTN      1380
TCCCTGGAGG TGGCGGAGGA GATCCGCCGC CTCGAGGAGG AGGTCTTCCG CCTGGCCGGC      1440
CACCCCTTCA ACCTCAACTC CCGGGACCAG CTGGAAAGGG TGCTCTTTGA CGAGCTNGGG      1500
CTTCCCGCCA TCGGCAAGAC GGAGAAGACN GGCAAGCGCT CCACCAGCGC CGCCGTGCTG      1560
GAGGCCCTNC GNGAGGCCCA CCCCATCGTG GAGAAGATCC TGCAGTACCG GGAGCTCACC      1620
AAGCTCAAGA ACACCTACAT NGACCCCTG CCNGNCCTCG TCCACCCAG GACGGGCCGC      1680

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CTCCACACCC GCTTCAACCA GACGGCCACG GCCACGGGCA GGCTTAGTAG CTCCGACCCC      1740
AACCTGCAGA ACATCCCCGT CCGCACCCCN CTGGGCCAGA GGATCCGCCG GGCCTTCGTG      1800
GCCCAGGAGG GNTGGGTGTT GGTGGCCCTG GACTATAGCC AGATAGAGCT CCGGGTCCTG      1860
GCCCACCTCT CCGGGGACGA GAACCTGATC CGGGTCTTCC AGGAGGGGAG GGACATCCAC      1920
ACCCAGACCG CCAGCTGGAT GTTCGGCGTC CCCC CGGAGG CCGTGGACCC CCTGATGCGC      1980
CGGGCGGCCA AGACCATCAA CTTCGGGGTC CTCTACGGCA TGTCCGCCCA CCGCCTCTCC      2040
CAGGAGCTTG CCATCCCCTA CGAGGAGGCG GTGGCCTTCA TTGAGCGCTA CTTCAGAGC      2100
TTCCCCAAGG TCGGGGCCTG GATTGAGAAG ACCCTGGAGG AGGGCAGGAG GCGGGGGTAC      2160
GTGGAGACCC TCTTCGGCCG CCGGCGCTAC GTGCCCACC TCAACGCCCC GGTGAAGAGC      2220
GTGCGGGAGG CGGCGGAGCG CATGGCCTTC AACATGCCCC TCCAGGGCAC CGCCGCCGAC      2280
CTCATGAAGC TGGCCATGGT GAAGCTCTTC CCCC GGCTNC AGGAAATGGG GGCCAGGATG      2340
CTCCTNCAGG TCCACGACGA GCTGGTCCTC GAGGCCCCCA AAGAGCGGGC GGAGNGGTG      2400
GCCGCTTTGG CCAAGGAGGT CATGGAGGGG GTCTATCCCC TGGCCGTGCC CCTGGAGGTG      2460
GAGGTGGGGA TGGGGGAGGA CTGGCTCTCC GCCAAGGAGT AG                          2502

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(2) INFORMATION FOR SEQ ID NO:8:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 833 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

```

Met Xaa Ala Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu
 1           5           10           15
Val Asp Gly His His Leu Ala Tyr Arg Thr Phe Phe Ala Leu Lys Gly
          20           25           30
Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala
          35           40           45
Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Xaa Val
          50           55           60
Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Glu Ala
          65           70           75           80
Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln Leu
          85           90           95
Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Xaa Arg Leu Glu
          100          105          110
Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Thr Leu Ala Lys Lys
          115          120          125
Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Arg Asp
          130          135          140

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Leu Tyr Gln Leu Leu Ser Asp Arg Ile Ala Val Leu His Pro Glu Gly
 145 150 155 160
 Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg Pro
 165 170 175
 Glu Gln Trp Val Asp Tyr Arg Ala Leu Xaa Gly Asp Pro Ser Asp Asn
 180 185 190
 Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Xaa Lys Leu Leu
 195 200 205
 Xaa Glu Trp Gly Ser Leu Glu Asn Leu Leu Lys Asn Leu Asp Arg Val
 210 215 220
 Lys Pro Xaa Xaa Arg Glu Lys Ile Xaa Ala His Met Glu Asp Leu Xaa
 225 230 235 240
 Leu Ser Xaa Xaa Leu Ser Xaa Val Arg Thr Asp Leu Pro Leu Glu Val
 245 250 255
 Asp Phe Ala Xaa Arg Arg Glu Pro Asp Arg Glu Gly Leu Arg Ala Phe
 260 265 270
 Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu Leu
 275 280 285
 Glu Xaa Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu Gly
 290 295 300
 Ala Phe Val Gly Phe Val Leu Ser Arg Pro Glu Pro Met Trp Ala Glu
 305 310 315 320
 Leu Leu Ala Leu Ala Ala Ala Arg Xaa Gly Arg Val His Arg Ala Xaa
 325 330 335
 Asp Pro Leu Xaa Gly Leu Arg Asp Leu Lys Glu Val Arg Gly Leu Leu
 340 345 350
 Ala Lys Asp Leu Ala Val Leu Ala Leu Arg Glu Gly Leu Asp Leu Xaa
 355 360 365
 Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser Asn
 370 375 380
 Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr Glu
 385 390 395 400
 Asp Ala Gly Glu Arg Ala Leu Leu Ser Glu Arg Leu Phe Xaa Asn Leu
 405 410 415
 Xaa Xaa Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Xaa Glu
 420 425 430
 Val Glu Lys Pro Leu Ser Arg Val Leu Ala His Met Glu Ala Thr Gly
 435 440 445
 Val Arg Leu Asp Val Ala Tyr Leu Gln Ala Leu Ser Leu Glu Val Ala
 450 455 460
 Glu Glu Ile Arg Arg Leu Glu Glu Glu Val Phe Arg Leu Ala Gly His
 465 470 475 480
 Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe Asp
 485 490 495

Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys Arg
 500 505 510
 Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro Ile
 515 520 525
 Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Asn Thr
 530 535 540
 Tyr Ile Asp Pro Leu Pro Xaa Leu Val His Pro Arg Thr Gly Arg Leu
 545 550 555 560
 His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser Ser
 565 570 575
 Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly Gln
 580 585 590
 Arg Ile Arg Arg Ala Phe Val Ala Glu Glu Gly Trp Xaa Leu Val Ala
 595 600 605
 Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser Gly
 610 615 620
 Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His Thr
 625 630 635 640
 Gln Thr Ala Ser Trp Met Phe Gly Val Pro Pro Glu Ala Val Asp Pro
 645 650 655
 Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr Gly
 660 665 670
 Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu Glu
 675 680 685
 Ala Val Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val Arg
 690 695 700
 Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr Val
 705 710 715 720
 Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Asn Ala Arg
 725 730 735
 Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met Pro
 740 745 750
 Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys Leu
 755 760 765
 Phe Pro Arg Leu Xaa Glu Met Gly Ala Arg Met Leu Leu Gln Val His
 770 775 780
 Asp Glu Leu Val Leu Glu Ala Pro Lys Xaa Arg Ala Glu Xaa Val Ala
 785 790 795 800
 Ala Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val Pro
 805 810 815
 Leu Glu Val Glu Val Gly Xaa Gly Glu Asp Trp Leu Ser Ala Lys Glu
 820 825 830

Xaa

(2) INFORMATION FOR SEQ ID NO:9:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 1647 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

ATGAATTCGG GGATGCTGCC CCTCTTTGAG CCCAAGGGCC GGGTCCTCCT GGTGGACGGC	60
CACCACCTGG CCTACCGCAC CTTCACGCC CTGAAGGGCC TCACCACCAG CCGGGGGGAG	120
CCGGTGCAGG CGGTCTACGG CTTCGCCAAG AGCCTCCTCA AGGCCCTCAA GGAGGACGGG	180
GACGCGGTGA TCGTGGTCTT TGACGCCAAG GCCCCTCCT TCCGCCACGA GGCCTACGGG	240
GGGTACAAGG CGGGCCGGGC CCCACGCCG GAGGACTTTC CCCGGCAACT CGCCCTCATC	300
AAGGAGCTGG TGGACCTCCT GGGGCTGGCG CGCCTCGAGG TCCCGGGCTA CGAGGCGGAC	360
GACGTCCTGG CCAGCCTGGC CAAGAAGGCG GAAAAGGAGG GCTACGAGGT CCGCATCCTC	420
ACCGCCGACA AAGACCTTTA CCAGCTCCTT TCCGACCGCA TCCACGTCCT CCACCCCGAG	480
GGGTACCTCA TCACCCCGGC CTGGCTTTGG GAAAAGTACG GCCTGAGGCC CGACCACTGG	540
GCCGACTACC GGGCCCTGAC CGGGGACGAG TCCGACAACC TTCCCGGGT CAAGGGCATC	600
GGGGAGAAGA CGGCGAGGAA GCTTCTGGAG GAGTGGGGGA GCCTGGAAGC CTCCTCAAG	660
AACCTGGACC GGCTGAAGCC CGCCATCCGG GAGAAGATCC TGGCCACAT GGACGATCTG	720
AAGCTCTCCT GGGACCTGGC CAAGGTGCGC ACCGACCTGC CCCTGGAGGT GGACTTCGCC	780
AAAAGGCGGG AGCCCGACCG GGAGAGGCTT AGGGCCTTTC TGGAGAGGCT TGAGTTTGGC	840
AGCCTCCTCC ACGAGTTCGG CCTTCTGGAA AGCCCAAGG CCCTGGAGGA GGCCCCCTGG	900
CCCCCGCCGG AAGGGGCCTT CGTGGGCTTT GTGCTTTCCC GCAAGGAGCC CATGTGGGCC	960
GATCTTCTGG CCCTGGCCGC CGCCAGGGGG GGGCCGGTCC ACCGGGCCCC CGAGCCTTAT	1020
AAAGCCCTCA GGGACCTGAA GGAGGCGCGG GGGCTTCTCG CCAAAGACCT GAGCGTTCTG	1080
GCCCTGAGGG AAGGCCTTGG CCTCCCGCCC GCGGACGACC CCATGCTCCT CGCCTACCTC	1140
CTGGACCCCT CCAACACCAC CCCCAGGGGG GTGGCCCGGC GCTACGGCGG GGAGTGGACG	1200
GAGGAGGCGG GGGAGCGGGC CGCCCTTTCC GAGAGGCTCT TCGCCAACCT GTGGGGGAGG	1260
CTTGAGGGGG AGGAGAGGCT CTTTGGCTT TACCGGGAGG TGGAGAGGCC CTTTCCGCT	1320
GTCCTGGCCC ACATGGAGGC CACGGGGGTG CGCCTGGACG TGGCCTATCT CAGGGCCTTG	1380
TCCCTGGAGG TGGCCGGGGA GATCGCCCGC CTCGAGGCCG AGGTCTTCCG CTTGGCCGGC	1440
CACCCCTTCA ACCTCAACTC CCGGGACCAG CTGGAAAGGG TCCTCTTTGA CGAGCTAGGG	1500
CTTCCCGCCA TCGGCAAGAC GGAGAAGACC GGCAAGCGCT CCACCAGCGC CGCCGTCCTG	1560
GAGGCCCTCC GCGAGGCCCA CCCCATCGTG GAGAAGATCC TGCAGGCATG CAAGCTTGGC	1620
ACTGGCCGTC GTTTTACAAC GTCGTGA	1647

(2) INFORMATION FOR SEQ ID NO:10:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 2088 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

ATGAATTCGG GGATGCTGCC CCTCTTTGAG CCCAAGGGCC GGTCTCTCCT GGTGGACGGC	60
CACCACCTGG CCTACCGCAC CTTCCACGCC CTGAAGGGCC TCACCACCAG CCGGGGGGAG	120
CCGGTGCAGG CGGTCTACGG CTTGCCAAG AGCCTCTCA AGGCCCTCAA GGAGGACGGG	180
GACGCGGTGA TCGTGGTCTT TGACGCCAAG GCCCCCTCCT TCCGCCACGA GGCCTACGGG	240
GGGTACAAGG CGGGCCGGGC CCCACGCCG GAGGACTTTC CCCGGCAACT CGCCCTCATC	300
AAGGAGCTGG TGGACCTCCT GGGGCTGGCG CGCCTCGAGG TCCCGGGCTA CGAGGCGGAC	360
GACGTCCTGG CCAGCCTGGC CAAGAAGGCG GAAAAGGAGG GCTACGAGGT CCGCATCTC	420
ACCGCCGACA AAGACCTTTA CCAGCTCCTT TCCGACCGCA TCCACGTCCT CCACCCGAG	480
GGGTACCTCA TCACCCCGGC CTGGCTTTGG GAAAAGTACG GCCTGAGGCC CGACCAGTGG	540
GCCGACTACC GGGCCCTGAC CGGGGACGAG TCCGACAACC TTCCCGGGGT CAAGGGCATC	600
GGGGAGAAGA CGGCGAGGAA GCTTCTGGAG GAGTGGGGGA GCCTGGAAGC CCTCCTCAAG	660
AACCTGGACC GGCTGAAGCC CGCCATCCGG GAGAAGATCC TGGCCACAT GGACGATCTG	720
AAGCTCTCCT GGGACCTGGC CAAGGTGCGC ACCGACCTGC CCCTGGAGGT GGACTTCGCC	780
AAAAGGCGGG AGCCCGACCG GGAGAGGCTT AGGGCCTTTC TGGAGAGGCT TGAGTTTGGC	840
AGCCTCCTCC ACGAGTTCGG CTTTCTGGAA AGCCCCAAGG CCCTGGAGGA GGCCCCCTGG	900
CCCCCGCCGG AAGGGGCCTT CGTGGGCTTT GTGCTTTCCC GCAAGGAGCC CATGTGGGCC	960
GATCTTCTGG CCCTGGCCGC CGCCAGGGGG GGCCGGGTCC ACCGGGCCCC CGAGCCTTAT	1020
AAAGCCCTCA GGGACCTGAA GGAGGCGCGG GGGCTTCTCG CCAAAGACCT GAGCGTTCTG	1080
GCCCTGAGGG AAGGCCTTGG CCTCCCGCCC GCGACGACC CCATGCTCCT CGCTACCTC	1140
CTGGACCTT CCAACACCAC CCCCAGGGGG GTGGCCCGGC GCTACGGCGG GGAGTGGACG	1200
GAGGAGGCGG GGGAGCGGGC CGCCCTTTCC GAGAGGCTCT TCGCCAACCT GTGGGGGAGG	1260
CTTGAGGGGG AGGAGAGGCT CTTTGGCTT TACCGGGAGG TGGAGAGGCC CTTTCCGCT	1320
GTCTTGCCCC ACATGGAGGC CACGGGGGTG CGCCTGGACG TGGCTATCT CAGGGCCTTG	1380
TCCCTGGAGG TGGCCGGGGA GATCGCCCGC CTCGAGGCCG AGGTCTTCCG CCTGGCCGGC	1440
CACCCCTTCA ACCTCAACTC CCGGACCGAG CTGGAAGGG TCCTCTTTGA CGAGCTAGGG	1500
CTTCCCGCCA TCGCAAGAC GGAGAAGACC GGCAAGCGCT CCACCAGCGC CGCCGTCCTG	1560
GAGGCCCTCC GCGAGGCCCA CCCATCGTG GAGAAGATCC TGCAGTACCG GGAGCTCACC	1620
AAGCTGAAGA GCACCTACAT TGACCCCTTG CCGGACCTCA TCCACCCAG GACGGGCCCGC	1680

CTCCACACCC GCTTCAACCA GACGGCCACG GCCACGGGCA GGCTAAGTAG CTCCGATCCC	1740
AACCTCCAGA ACATCCCCGT CCGCACCCCG CTTGGGCAGA GGATCCGCCG GGCCTTCATC	1800
GCCGAGGAGG GGTGGCTATT GGTGGCCCTG GACTATAGCC AGATAGAGCT CAGGGTGCTG	1860
CCCCACCTCT CCGGCGACGA GAACCTGATC CGGTCTTCC AGGAGGGGCG GGACATCCAC	1920
ACGGAGACCG CCAGCTGGAT GTTCGGCGTC CCCCgggAGG CCGTGGACCC CCTGATGCGC	1980
CGGGCGGCCA AGACCATCAA CTTCGGGGTC CTCTACGGCA TGTCGGCCCA CCGCCTCTCC	2040
CAGGAGCTAG CTAGCCATCC CTTACGAGGA GGCCAGGCC TTCATTGA	2088

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 962 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

ATGAATTCGG GGATGCTGCC CCTCTTTGAG CCCAAGGGCC GGGTCCTCCT GGTGGACGGC	60
CACCACCTGG CCTACCGCAC CTTCCACGCC CTGAAGGGCC TCACCACCAG CCGGGGGGAG	120
CCGGTGCAGG CCGTCTACGG CTTCCGCAAG AGCCTCCTCA AGGCCCTCAA GGAGGACGGG	180
GACGCGGTGA TCGTGGTCTT TGACGCCAAG GCCCCCTCCT TCCGCCACGA GGCCTACGGG	240
GGGTACAAGG CGGGCCGGGC CCCACGCCG GAGGACTTTC CCCGGCAACT CGCCCTCATC	300
AAGGAGCTGG TGGACCTCCT GGGGCTGGCG CGCCTCGAGG TCCCGGGCTA CGAGGCGGAC	360
GACGTCCTGG CCAGCCTGGC CAAGAAGGCG GAAAAGGAGG GCTACGAGGT CCGCATCCTC	420
ACCGCCGACA AAGACCTTTA CCAGCTTCTT TCCGACCGCA TCCACGTCCT CCACCCCGAG	480
GGGTACCTCA TCACCCCGGC CTGGCTTTGG GAAAAGTACG GCCTGAGGCC CGACCACTGG	540
GCCGACTACC GGGCCCTGAC CGGGGACGAG TCCGACAACC TTCCCGGGGT CAAGGGCATC	600
GGGGAGAAGA CGGCGAGGAA GCTTCTGGAG GAGTGGGGGA GCCTGGAAGC CCTCTCAAG	660
AACCTGGACC GGCTGAAGCC CGCCATCCGG GAGAAGATCC TGGCCACAT GGACGATCTG	720
AAGCTCTCCT GGGACCTGGC CAAGGTGCGC ACCGACCTGC CCCTGGAGGT GGA CTTCGCC	780
AAAAGGCGGG AGCCCGACCG GGAGAGGCTT AGGGCCTTTC TGGAGAGGCT TGAGTTTGGC	840
AGCCTCCTCC ACGAGTTCGG CTTCTGGAA AGCCCCAAGT CATGGAGGGG GTGTATCCCC	900
TGGCCGTGCC CCTGGAGGTG GAGGTGGGGA TAGGGGAGGA CTGGCTCTCC GCCAAGGAGT	960
GA	962

(2) INFORMATION FOR SEQ ID NO:12:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 1600 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

ATGGAATTGC GGGATGCTGC CCCTCTTTGA GCCCAAGGGC CGGTCCTCC TGGTGGACGG	60
CCACCACCTG GCCTACCGCA CCTTCCACGC CTGAAGGGC CTCACCACCA GCCGGGGGGA	120
GCCGGTGCG GCGGTCTACG GCTTCGCCAA GAGCCTCCTC AAGGCCCTCA AGGAGGACGG	180
GGACGCGGTG ATCGTGGTCT TTGACGCCAA GGCCCCCTCC TTCCGCCACG AGGCCTACGG	240
GGGTACAA GCGGGCCGGG CCCCCACGCC GGAGGACTTT CCCCAGCAAC TCGCCCTCAT	300
CAAGGAGCTG GTGGACCTCC TGGGGCTGGC GCGCCTCGAG GTCCCGGGCT ACGAGGCGGA	360
CGACGTCCTG GCCAGCCTGG CCAAGAAGGC GGAAAAGGAG GGCTACGAGG TCCGCATCCT	420
CACCGCCGAC AAAGACCTTT ACCAGCTCCT TTCCGACCGC ATCCACGTCC TCCACCCCGA	480
GGGTACCTC ATCACCCCGG CCTGGCTTTG GGAAAAGTAC GGCTTGAGGC CCGACCACTG	540
GGCCGACTAC CGGGCCCTGA CCGGGGACGA GTCCGACAAC CTTCCTGGGG TCAAGGGCAT	600
CGGGGAGAAG ACGGCGAGGA AGCTTCTGGA GGAGTGGGGG AGCCTGGAAG CCCTCTCAA	660
GAACCTGGAC CGGTGAAGC CCGCCATCCG GGAGAAGATC CTGGCCACA TGGACGATCT	720
GAAGCTCTCC TGGGACCTGG CCAAGGTGCG CACCGACCTG CCCCTGGAGG TGGACTTCGC	780
CAAAAGGCGG GAGCCCGACC GGGAGAGGCT TAGGGCCTTT CTGGAGAGGC TTGAGTTGG	840
CAGCCTCCTC CACGAGTTCG GCCTTCTGGA AAGCCCCAAG ATCCGCCGGG CCTTCATCGC	900
CGAGGAGGGG TGGCTATTGG TGGCCCTGGA CTATAGCCAG ATAGAGCTCA GGGTGCTGGC	960
CCACCTCTCC GCGGACGAGA ACCTGATCCG GGTCTTCCAG GAGGGGCGGG ACATCCACAC	1020
GGAGACCGCC AGCTGGATGT TCGGCGTCCC CCGGGAGGCC GTGGACCCCC TGATGCGCCG	1080
GGCGGCCAAG ACCATCAACT TCGGGTCCT CTACGGCATG TCGGCCACC GCCTCTCCA	1140
GGAGCTAGCC ATCCCTTACG AGGAGGCCCA GGCCTTCATT GAGCGCTACT TTCAGAGCTT	1200
CCCCAAGGTG CGGGCCTGGA TTGAGAAGAC CCTGGAGGAG GGCAGGAGGC GGGGTACGT	1260
GGAGACCTC TTCGGCCGCC GCCGCTACGT GCCAGACCTA GAGGCCGGG TGAAGAGCGT	1320
GCGGGAGGCG GCCGAGCGCA TGGCCTTCAA CATGCCGTC CGGGGCACCG CCGCCGACCT	1380
CATGAAGCTG GCTATGGTGA AGCTCTTCCC CAGGCTGGAG GAAATGGGG CCAGGATGCT	1440
CCTTCAGGTC CACGACGAGC TGGTCCTCGA GGCCCCAAA GAGAGGGCGG AGGCCGTGGC	1500
CCGGCTGGCC AAGGAGGTCA TGGAGGGGGT GATCCCCCTG GCCGTGCCCC TGGAGGTGGA	1560
GGTGGGATA GGGGAGGACT GGCTCTCCGC CAAGGAGTGA	1600

(2) INFORMATION FOR SEQ ID NO:13:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 36 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

CACGAATTCG GGGATGCTGC CCCTCTTTGA GCCCAA

36

(2) INFORMATION FOR SEQ ID NO:14:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 34 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

GTGAGATCTA TCACTCCTTG GCGGAGAGCC AGTC

34

(2) INFORMATION FOR SEQ ID NO:15:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 91 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

TAATACGACT CACTATAGGG AGACCGAAT TCGAGCTCGC CCGGGCGAGC TCGAATTCG

60

TGTATCTAT AGTGTACCT AAATCGAATT C

91

(2) INFORMATION FOR SEQ ID NO:16:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

TAATACGACT CACTATAGGG

20

(2) INFORMATION FOR SEQ ID NO:17:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 27 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:
GAATTCGATT TAGGTGACAC TATAGAA 27

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 31 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:
GTAATCATGG TCATAGCTGG TAGCTTGCTA C 31

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 42 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:
GGATCCTCTA GAGTCGACCT GCAGGCATGC CTACCTTGGT AG 42

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:
GGATCCTCTA GAGTCGACCT GCAGGCATGC 30

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 2502 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:
ATGAATTCGG GGATGCTGCC CTTCTTTGAG CCCAAGGGCC GGGTCCTCCT GGTGGACGGC 60
CACCACCTGG CTTACCGCAC CTTCACGCC CTGAAGGGCC TCACCACCAG CCGGGGGGAG 120
CCGGTGCAGG CGGTCTACGG CTTGCCAAG AGCCTCCTCA AGGCCCTCAA GGAGGACGGG 180
GACGCGGTGA TCGTGGTCTT TGACGCCAAG GCCCCTCCT TCCGCCACGA GGCCTACGGG 240
GGGTACAAGG CGGGCCGGGC CCCACGCCG GAGGACTTTC CCCGGCAACT CGCCCTCATC 300

AAGGAGCTGG	TGGACCTCCT	GGGGCTGGCG	CGCCTCGAGG	TCCCGGGCTA	CGAGGCGGAC	360
GACGTCTTGG	CCAGCCTGGC	CAAGAAGGCG	GAAAAGGAGG	GCTACGAGGT	CCGCATCCTC	420
ACCGCCGACA	AAGACCTTTA	CCAGCTCCTT	TCCGACCGCA	TCCACGTCCT	CCACCCCGAG	480
GGGTACCTCA	TCACCCCGGC	CTGGCTTTGG	GAAAAGTACG	GCCTGAGGCC	CGACCAGTGG	540
GCCGACTACC	GGGCCCTGAC	CGGGGACGAG	TCCGACAACC	TTCCCGGGGT	CAAGGGCATC	600
GGGGAGAAGA	CGGCGAGGAA	GCTTCTGGAG	GAGTGGGGGA	GCCTGGAAGC	CCTCCTCAAG	660
AACCTGGACC	GGCTGAAGCC	CGCCATCCGG	GAGAAGATCC	TGGCCACAT	GGACGATCTG	720
AAGCTCTCCT	GGGACCTGGC	CAAGGTGCGC	ACCGACCTGC	CCCTGGAGGT	GGACTTCGCC	780
AAAAGCGGGG	AGCCCGACCG	GGAGAGGCTT	AGGGCCTTTC	TGGAGAGGCT	TGAGTTTGGC	840
AGCCTCTCC	ACGAGTTCGG	CCTTCTGGAA	AGCCCCAAGG	CCCTGGAGGA	GGCCCCCTGG	900
CCCCCGCCGG	AAGGGGCCTT	CGTGGGCTTT	GTGCTTTCCC	GCAAGGAGCC	CATGTGGGCC	960
GATCTTCTGG	CCCTGGCCGC	CGCCAGGGGG	GGCCGGGTCC	ACCGGGCCCC	CGAGCCTTAT	1020
AAAGCCCTCA	GGGACCTGAA	GGAGGCGCGG	GGGCTTCTCG	CCAAAGACCT	GAGCGTTCTG	1080
GCCCTGAGGG	AAGGCCTTGG	CCTCCCGCCC	GGCGACGACC	CCATGCTCCT	CGCCTACCTC	1140
CTGGACCCTT	CCAACACCAC	CCCCGAGGGG	GTGGCCCGGC	GCTACGGCGG	GGAGTGGACG	1200
GAGGAGGCGG	GGGAGCGGGC	CGCCCTTTCC	GAGAGGCTCT	TCGCCAACCT	GTGGGGGAGG	1260
CTTGAGGGGG	AGGAGAGGCT	CCTTTGGCTT	TACCGGGAGG	TGGAGAGGCC	CCTTTCGGCT	1320
GTCTTGCCCC	ACATGGAGGC	CACGGGGGTG	CGCCTGGACG	TGGCCTATCT	CAGGGCCTTG	1380
TCCCTGGAGG	TGGCCGGGGA	GATCGCCCGC	CTCGAGGCCG	AGGTCTTCCG	CCTGGCCGGC	1440
CACCCCTTCA	ACCTCAACTC	CCGGGACCAG	CTGGAAAGGG	TCCTCTTTGA	CGAGCTAGGG	1500
CTTCCCGCCA	TCGGCAAGAC	GGAGAAGACC	GGCAAGCGCT	CCACCAGCGC	CGCCGTCCTG	1560
GAGGCCCTCC	GCGAGGCCCA	CCCCATCGTG	GAGAAGATCC	TGCAGTACCG	GGAGCTCACC	1620
AAGCTGAAGA	GCACCTACAT	TGACCCCTTG	CCGGACCTCA	TCCACCCAG	GACGGGCCGC	1680
CTCCACACCC	GCTTCAACCA	GACGGCCACG	GCCACGGGCA	GGCTAAGTAG	CTCCGATCCC	1740
AACCTCCAGA	ACATCCCCGT	CCGCACCCCG	CTTGGGCAGA	GGATCCGCCG	GGCCTTCATC	1800
GCCGAGGAGG	GGTGGCTATT	GGTGGCCCTG	GACTATAGCC	AGATAGAGCT	CAGGGTGCTG	1860
GCCCACCTCT	CCGGCGACGA	GAACCTGATC	CGGGTCTTCC	AGGAGGGGCG	GGACATCCAC	1920
ACGGAGACCG	CCAGCTGGAT	GTTCGGCGTC	CCCCGGGAGG	CCGTGGACCC	CCTGATGCGC	1980
CGGGCGGCCA	AGACCATCAA	CTTCGGGGTC	CTCTACGGCA	TGTCGGCCCA	CCGCCTCTCC	2040
CAGGAGCTAG	CCATCCCTTA	CGAGGAGGCC	CAGGCCTTCA	TTGAGCGCTA	CTTTCAGAGC	2100
TTCCCCAAGG	TGCGGGCCTG	GATTGAGAAG	ACCCTGGAGG	AGGGCAGGAG	GCGGGGGTAC	2160
GTGGAGACCC	TCTTCGGCCG	CCGCCGCTAC	GTGCCAGACC	TAGAGGCCCG	GGTGAAGAGC	2220
GTGCGGGAGG	CGGCCGAGCG	CATGGCCTTC	AACATGCCCG	TCCGGGGCAC	CGCCGCCGAC	2280
CTCATGAAGC	TGGCTATGGT	GAAGCTCTTC	CCCAGGCTGG	AGGAAATGGG	GGCCAGGATG	2340

CTCCTTCAGG TCCACGACGA GCTGGTCCTC GAGGCCCCAA AAGAGAGGGC GGAGGCCGTG 2400
 GCCCCGCTGG CCAAGGAGGT CATGGAGGGG GTGTATCCCC TGGCCGTGCC CCTGGAGGTG 2460
 GAGGTGGGGA TAGGGGAGGA CTGGCTCTCC GCCAAGGAGT GA 2502

(2) INFORMATION FOR SEQ ID NO:22:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 19 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

GATTTAGGTG AACTATAG

19

(2) INFORMATION FOR SEQ ID NO:23:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 50 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

ACACAGGTAC CACATGGTAC AAGAGGCAAG AGAGACGACA CAGCAGAAAC

50

(2) INFORMATION FOR SEQ ID NO:24:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 15 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: unknown

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

Met Ala Ser Met Thr Gly Gly Gln Gln Met Gly Arg Ile Asn Ser
 1 5 10 15

(2) INFORMATION FOR SEQ ID NO:25:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 969 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

ATGGCTAGCA TGACTGGTGG ACAGCAAATG GGTCGGATCA ATTCGGGGAT GCTGCCCTC 60
 TTTGAGCCCA AGGGCCGGGT CCTCTGGTG GACGGCCACC ACCTGGCCTA CCGCACCTTC 120
 CACGCCCTGA AGGGCCTCAC CACCAGCCGG GGGGAGCCGG TGCAGGCGGT CTACGGCTTC 180

GCCAAGAGCC TCCTCAAGGC CCTCAAGGAG GACGGGGACG CGGTGATCGT GGTCTTTGAC	240
GCCAAGGCCC CCTCCTTCCG CCACGAGGCC TACGGGGGGT ACAAGGCGGG CCGGGCCCCC	300
ACGCCGGAGG ACTTTCCCCG GCAACTCGCC CTCATCAAGG AGCTGGTGGA CCTCCTGGGG	360
CTGGCGCGCC TCGAGGTCCC GGGCTACGAG GCGGACGACG TCCTGGCCAG CCTGGCCAAG	420
AAGGCCGAAA AGGAGGGCTA CGAGGTCCGC ATCCTCACCG CCGACAAAGA CCTTTACCAG	480
CTTCTTCCG ACCGCATCCA CGTCCTCCAC CCCGAGGGT ACCTCATCAC CCCGGCCTGG	540
CTTTGGGAAA AGTACGGCCT GAGGCCCGAC CAGTGGGCCG ACTACCGGGC CCTGACCGGG	600
GACGAGTCCG ACAACCTTCC CGGGGTCAAG GGCATCGGGG AGAAGACGGC GAGGAAGCTT	660
CTGGAGGAGT GGGGAGCCT GGAAGCCCTC CTCAAGAACC TGGACCGGCT GAAGCCCGCC	720
ATCCGGGAGA AGATCCTGGC CCACATGGAC GATCTGAAGC TCTCCTGGGA CCTGGCCAAG	780
GTGCGCACCG ACCTGCCCCCT GGAGGTGGAC TTCGCCAAAA GCGGGGAGCC CGACCGGGAG	840
AGGCTTAGGG CCTTTCTGGA GAGGCTTGAG TTTGGCAGCC TCCTCCACGA GTTCGGCCTT	900
CTGGAAAGCC CCAAGTCATG GAGGGGTGT ATCCCTGGC CGTGCCCTG GAGGTGGAGG	960
TGGGGATAG	969

(2) INFORMATION FOR SEQ ID NO:26:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 948 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

ATGGCTAGCA TGACTGGTGG ACAGCAAATG GGTCCGATCA ATTCGGGGAT GCTGCCCCCTC	60
TTTGAGCCCA AGGGCCGGGT CCTCCTGGTG GACGGCCACC ACCTGGCCTA CCGCACCTTC	120
CACGCCCTGA AGGGCCTCAC CACCAGCCGG GGGGAGCCGG TGCAGGCGGT CTACGCTTC	180
GCCAAGAGCC TCCTCAAGGC CCTCAAGGAG GACGGGGACG CGGTGATCGT GGTCTTTGAC	240
GCCAAGGCCC CCTCCTTCCG CCACGAGGCC TACGGGGGGT ACAAGGCGGG CCGGGCCCCC	300
ACGCCGGAGG ACTTTCCCCG GCAACTCGCC CTCATCAAGG AGCTGGTGGA CCTCCTGGGG	360
CTGGCGCGCC TCGAGGTCCC GGGCTACGAG GCGGACGACG TCCTGGCCAG CCTGGCCAAG	420
AAGGCCGAAA AGGAGGGCTA CGAGGTCCGC ATCCTCACCG CCGACAAAGA CCTTTACCAG	480
CTTCTTCCG ACCGCATCCA CGTCCTCCAC CCCGAGGGT ACCTCATCAC CCCGGCCTGG	540
CTTTGGGAAA AGTACGGCCT GAGGCCCGAC CAGTGGGCCG ACTACCGGGC CCTGACCGGG	600
GACGAGTCCG ACAACCTTCC CGGGGTCAAG GGCATCGGGG AGAAGACGGC GAGGAAGCTT	660
CTGGAGGAGT GGGGAGCCT GGAAGCCCTC CTCAAGAACC TGGACCGGCT GAAGCCCGCC	720
ATCCGGGAGA AGATCCTGGC CCACATGGAC GATCTGAAGC TCTCCTGGGA CCTGGCCAAG	780
GTGCGCACCG ACCTGCCCCCT GGAGGTGGAC TTCGCCAAAA GCGGGGAGCC CGACCGGGAG	840

AGGCTTAGGG CCTTTCTGGA GAGGCTTGAG TTTGGCAGCC TCCTCCACGA GTTCGGCCTT 900
CTGGAAAGCC CCAAGGCCGC ACTCGAGCAC CACCACCACC ACCACTGA 948

(2) INFORMATION FOR SEQ ID NO:27:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 206 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

CGCCAGGGTT TTCCAGTCA CGACGTTGTA AAACGACGGC CAGTGAATTG TAATACGACT 60
CACTATAGGG CGAATTCGAG CTCGGTACCC GGGGATCCTC TAGAGTCGAC CTGCAGGCAT 120
GCAAGCTTGA GTATTCTATA GTGTACCTA AATAGCTTGG CGTAATCATG GTCATAGCTG 180
TTTCCTGTGT GAAATTGTTA TCCGCT 206

(2) INFORMATION FOR SEQ ID NO:28:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

AACAGCTATG ACCATGATTA C 21

(2) INFORMATION FOR SEQ ID NO:29:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 60 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:29:

GTCTCTGCT CTCTGGTCGC TGTCTCGCTT GTGAAACAAG CGAGACAGCG TGGTCTCTCG 60

(2) INFORMATION FOR SEQ ID NO:30:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 15 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:30:

CGAGAGACCA CGCTG 15

(2) INFORMATION FOR SEQ ID NO:31:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 52 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:31:

CCTTTCGCTT TCTTCCCTTC CTTTCTCGCC ACGTTCGCCG GCTTTCCCCG TC

52

(2) INFORMATION FOR SEQ ID NO:32:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 26 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:32:

AGAAAGGAAG GGAAGAAAGC GAAAGG

26

(2) INFORMATION FOR SEQ ID NO:33:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 21 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:33:

GACGGGGAAA GCCGGCGAAC G

21

(2) INFORMATION FOR SEQ ID NO:34:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:34:

GAAAGCCGGC GAACGTGGCG

20

(2) INFORMATION FOR SEQ ID NO:35:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 21 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:35:

GGCGAACGTG GCGAGAAAGG A

21

(2) INFORMATION FOR SEQ ID NO:36:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 42 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:36:

CCTTTCGCTT TCTTCCCTTC CTTTCTCGCC ACGTTCGCCG GC

42

(2) INFORMATION FOR SEQ ID NO:37:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 42 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:37:

CCTTTCGCTC TCTTCCCTTC CTTTCTCGCC ACGTTCGCCG GC

42

(2) INFORMATION FOR SEQ ID NO:38:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 27 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 8
 - (C) IDENTIFICATION METHOD: experimental
 - (D) OTHER INFORMATION: /evidence= EXPERIMENTAL

/mod_base= OTHER

/note= "The A residue at this position is 2'-O-methyladenosine."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:38:

AGAAAGGAAG GGAAGAAAGC GAAAGGT

27

(2) INFORMATION FOR SEQ ID NO:39:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 24 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:39:

GCCGGCGAAC GTGGCGAGAA AGGA

24

(2) INFORMATION FOR SEQ ID NO:40:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:40:

GGTTTTTCTT TGAGGTTTAG

20

(2) INFORMATION FOR SEQ ID NO:41:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 19 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:41:

GCGACACTCC ACCATAGAT

19

(2) INFORMATION FOR SEQ ID NO:42:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 19 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:42:

CTGTCTTCAC GCAGAAAGC

19

(2) INFORMATION FOR SEQ ID NO:43:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 19 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:43:

GCACGGTCTA CGAGACCTC

19

(2) INFORMATION FOR SEQ ID NO:44:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:44:

TAATACGACT CACTATAGGG

20

(2) INFORMATION FOR SEQ ID NO:45:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 337 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: RNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:45:

GGGAAAGCUU GCAUGCCUGC AGGUCGACUC UAGAGGAUCU ACUAGUCAUA UGGAUUCUGU	60
CUUCACGCAG AAAGCGUCUG GCCAUGGCGU UAGUAUGAGU GUCGUGCAGC CUCCAGGACC	120
CCCCCUCGCC GGAGAGGCAU AGUGGUCUGC GGAACCGGUG AGUACACCGG AAUUGCCAGG	180
ACGACCGGGU CCUUUCUUGG AUAACCCGC UCAAUGCCUG GAGAUUUGGG CGUGCCCCCG	240
CAAGACUGCU AGCCGAGUAG UGUUGGGUCG CGAAAGGCCU UGUGGUACUG CCUGAUAGGG	300
UGCCUGCGAG UGCCCCGGGA GGUCUCGUAG ACCGUGC	337

(2) INFORMATION FOR SEQ ID NO:46:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(ix) FEATURE:

- (A) NAME/KEY: misc_feature
 - (B) LOCATION: 18
 - (C) IDENTIFICATION METHOD: experimental
 - (D) OTHER INFORMATION: /evidence= EXPERIMENTAL
- /note= "The N at this position indicates the presence of a fluorescein dye on an abasic linker."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:46:

CCGGTCGTCC TGGCAATNCC

20

(2) INFORMATION FOR SEQ ID NO:47:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 24 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:47:

GTTTATCCAA GAAAGGACCC GGTC

24

(2) INFORMATION FOR SEQ ID NO:48:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:48:

CAGGGTGAAG GGAAGAAGAA AGCGAAAGGT

30

(2) INFORMATION FOR SEQ ID NO:49:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:49:

CAGGGGGAAG GGAAGAAGAA AGCGAAAGGT

30

(2) INFORMATION FOR SEQ ID NO:50:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 22 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 1..2
 - (C) IDENTIFICATION METHOD: experimental
 - (D) OTHER INFORMATION: /evidence= EXPERIMENTAL

/mod_base= OTHER

/note= "The T residues at positions 1 and 2 are amino modified T residues."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:50:

TTCTTTTCAC CAGCGAGACG GG

22

(2) INFORMATION FOR SEQ ID NO:51:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 22 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:51:

ATTGGGCGCC AGGGTGGTTT TT

22

(2) INFORMATION FOR SEQ ID NO:52:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 53 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:52:

CCCGTCTCGC TGGTGAAAAG AAAAACCACC CTGGCGCCCA ATACGCAAAC CGC

53

(2) INFORMATION FOR SEQ ID NO:53:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 31 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:53:

GAATTCGATT TAGGTGACAC TATAGAATAC A

31

(2) INFORMATION FOR SEQ ID NO:54:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 42 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:54:

CCTTTCGCTT TCTTCCCTTC CTTTCTCGCC ACGTTCGCCG GC

42

(2) INFORMATION FOR SEQ ID NO:55:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 24 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:55:

GCCGGCGAAC GTGGCGAGAA AGGA

24

(2) INFORMATION FOR SEQ ID NO:56:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 26 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:56:
CAGAAGGAAG GGAAGAAAGC GAAAGG 26

(2) INFORMATION FOR SEQ ID NO:57:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 26 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:57:
CAGGGGGAAG GGAAGAAAGC GAAAGG 26

(2) INFORMATION FOR SEQ ID NO:58:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 26 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:58:
CAGGGTACAG GGAAGAAAGC GAAAGG 26

(2) INFORMATION FOR SEQ ID NO:59:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 42 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:59:
GGGAAAGTCC TCGGAGCCGC GCGGGACGAG CGTGGGGGCC CG 42

(2) INFORMATION FOR SEQ ID NO:60:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 963 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: double
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(ix) FEATURE:
(A) NAME/KEY: CDS
(B) LOCATION: 1..960

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:60:
ATG GCT AGC ATG ACT GGT GGA CAG CAA ATG GGT CGG ATC AAT TCG GGG 48
Met Ala Ser Met Thr Gly Gly Gln Gln Met Gly Arg Ile Asn Ser Gly
1 5 10 15

ATG CTG CCC CTC TTT GAG CCC AAG GGC CGG GTC CTC CTG GTG GAC GGC Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu Leu Val Asp Gly 20 25 30	96
CAC CAC CTG GCC TAC CGC ACC TTC CAC GCC CTG AAG GGC CTC ACC ACC His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys Gly Leu Thr Thr 35 40 45	144
AGC CGG GGG GAG CCG GTG CAG GCG GTC TAC GGC TTC GCC AAG AGC CTC Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe Ala Lys Ser Leu 50 55 60	192
CTC AAG GCC CTC AAG GAG GAC GGG GAC GCG GTG ATC GTG GTC TTT GAC Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile Val Val Phe Asp 65 70 75 80	240
GCC AAG GCC CCC TCC TTC CGC CAC GAG GCC TAC GGG GGG TAC AAG GCG Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly Gly Tyr Lys Ala 85 90 95	288
GGC CGG GCC CCC ACG CTC GTC CCG CGC GGC TCC GAG GAC TTT CCC CGG Gly Arg Ala Pro Thr Leu Val Pro Arg Gly Ser Glu Asp Phe Pro Arg 100 105 110	336
CAA CTC GCC CTC ATC AAG GAG CTG GTG GAC CTC CTG GGG CTG GCG CGC Gln Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg 115 120 125	384
CTC GAG GTC CCG GGC TAC GAG GCG GAC GAC GTC CTG GCC AGC CTG GCC Leu Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala 130 135 140	432
AAG AAG GCG GAA AAG GAG GGC TAC GAG GTC CGC ATC CTC ACC GCC GAC Lys Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp 145 150 155 160	480
AAA GAC CTT TAC CAG CTC CTT TCC GAC CGC ATC CAC GTC CTC CAC CCC Lys Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro 165 170 175	528
GAG GGG TAC CTC ATC ACC CCG GCC TGG CTT TGG GAA AAG TAC GGC CTG Glu Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu 180 185 190	576
AGG CCC GAC CAG TGG GCC GAC TAC CGG GCC CTG ACC GGG GAC GAG TCC Arg Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser 195 200 205	624
GAC AAC CTT CCC GGG GTC AAG GGC ATC GGG GAG AAG ACG GCG AGG AAG Asp Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys 210 215 220	672
CTT CTG GAG GAG TGG GGG AGC CTG GAA GCC CTC CTC AAG AAC CTG GAC Leu Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp 225 230 235 240	720
CGG CTG AAG CCC GCC ATC CGG GAG AAG ATC CTG GCC CAC ATG GAC GAT Arg Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp 245 250 255	768
CTG AAG CTC TCC TGG GAC CTG GCC AAG GTG CGC ACC GAC CTG CCC CTG Leu Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu 260 265 270	816
GAG GTG GAC TTC GCC AAA AGG CGG GAG CCC GAC CGG GAG AGG CTT AGG Glu Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg 275 280 285	864

GCC TTT CTG GAG AGG CTT GAG TTT GGC AGC CTC CTC CAC GAG TTC GGC	912
Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly	
290 295 300	
CTT CTG GAA AGC CCC AAG GCC GCA CTC GAG CAC CAC CAC CAC CAC CAC	960
Leu Leu Glu Ser Pro Lys Ala Ala Leu Glu His His His His His His	
305 310 315 320	
TGA	963

(2) INFORMATION FOR SEQ ID NO:61:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 320 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:61:

Met	Ala	Ser	Met	Thr	Gly	Gly	Gln	Gln	Met	Gly	Arg	Ile	Asn	Ser	Gly	
1				5					10					15		
Met	Leu	Pro	Leu	Phe	Glu	Pro	Lys	Gly	Arg	Val	Leu	Leu	Val	Asp	Gly	
			20					25					30			
His	His	Leu	Ala	Tyr	Arg	Thr	Phe	His	Ala	Leu	Lys	Gly	Leu	Thr	Thr	
		35				40						45				
Ser	Arg	Gly	Glu	Pro	Val	Gln	Ala	Val	Tyr	Gly	Phe	Ala	Lys	Ser	Leu	
		50				55					60					
Leu	Lys	Ala	Leu	Lys	Glu	Asp	Gly	Asp	Ala	Val	Ile	Val	Val	Phe	Asp	
65				70				75						80		
Ala	Lys	Ala	Pro	Ser	Phe	Arg	His	Glu	Ala	Tyr	Gly	Gly	Tyr	Lys	Ala	
			85					90						95		
Gly	Arg	Ala	Pro	Thr	Leu	Val	Pro	Arg	Gly	Ser	Glu	Asp	Phe	Pro	Arg	
		100					105						110			
Gln	Leu	Ala	Leu	Ile	Lys	Glu	Leu	Val	Asp	Leu	Leu	Gly	Leu	Ala	Arg	
		115				120						125				
Leu	Glu	Val	Pro	Gly	Tyr	Glu	Ala	Asp	Asp	Val	Leu	Ala	Ser	Leu	Ala	
		130				135					140					
Lys	Lys	Ala	Glu	Lys	Glu	Gly	Tyr	Glu	Val	Arg	Ile	Leu	Thr	Ala	Asp	
145				150				155						160		
Lys	Asp	Leu	Tyr	Gln	Leu	Leu	Ser	Asp	Arg	Ile	His	Val	Leu	His	Pro	
			165					170						175		
Glu	Gly	Tyr	Leu	Ile	Thr	Pro	Ala	Trp	Leu	Trp	Glu	Lys	Tyr	Gly	Leu	
			180					185					190			
Arg	Pro	Asp	Gln	Trp	Ala	Asp	Tyr	Arg	Ala	Leu	Thr	Gly	Asp	Glu	Ser	
		195					200					205				
Asp	Asn	Leu	Pro	Gly	Val	Lys	Gly	Ile	Gly	Glu	Lys	Thr	Ala	Arg	Lys	
	210					215				220						
Leu	Leu	Glu	Glu	Trp	Gly	Ser	Leu	Glu	Ala	Leu	Leu	Lys	Asn	Leu	Asp	
225				230						235				240		

Arg Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp
 245 250 255

Leu Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu
 260 265 270

Glu Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg
 275 280 285

Ala Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly
 290 295 300

Leu Leu Glu Ser Pro Lys Ala Ala Leu Glu His His His His His His
 305 310 315 320

(2) INFORMATION FOR SEQ ID NO:62:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 20 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:62:

CGATCTCCTC GGCCACCTCC

20

(2) INFORMATION FOR SEQ ID NO:63:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 20 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:63:

GGCGGTGCCC TGGACGGGCA

20

(2) INFORMATION FOR SEQ ID NO:64:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 20 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:64:

CCAGCTCGTT GTGGACCTGA

20

(2) INFORMATION FOR SEQ ID NO:65:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2505 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..2499

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:65:

ATG AAT TCG GGG ATG CTG CCC CTC TTT GAG CCC AAG GGC CGG GTC CTC	48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu	
1 5 10 15	
CTG GTG GAC GGC CAC CAC CTG GCC TAC CGC ACC TTC CAC GCC CTG AAG	96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys	
20 25 30	
GGC CTC ACC ACC AGC CGG GGG GAG CCG GTG CAG GCG GTC TAC GGC TTC	144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe	
35 40 45	
GCC AAG AGC CTC CTC AAG GCC CTC AAG GAG GAC GGG GAC GCG GTG ATC	192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile	
50 55 60	
GTG GTC TTT GAC GCC AAG GCC CCC TCC TTC CGC CAC GAG GCC TAC GGG	240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly	
65 70 75 80	
GGG TAC AAG GCG GGC CGG GCC CCC ACG CCG GAG GAC TTT CCC CGG CAA	288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln	
85 90 95	
CTC GCC CTC ATC AAG GAG CTG GTG GAC CTC CTG GGG CTG GCG CGC CTC	336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu	
100 105 110	
GAG GTC CCG GGC TAC GAG GCG GAC GAC GTC CTG GCC AGC CTG GCC AAG	384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys	
115 120 125	
AAG GCG GAA AAG GAG GGC TAC GAG GTC CGC ATC CTC ACC GCC GAC AAA	432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys	
130 135 140	
GAC CTT TAC CAG CTC CTT TCC GAC CGC ATC CAC GTC CTC CAC CCC GAG	480
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu	
145 150 155 160	
GGG TAC CTC ATC ACC CCG GCC TGG CTT TGG GAA AAG TAC GGC CTG AGG	528
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg	
165 170 175	
CCC GAC CAG TGG GCC GAC TAC CGG GCC CTG ACC GGG GAC GAG TCC GAC	576
Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp	
180 185 190	
AAC CTT CCC GGG GTC AAG GGC ATC GGG GAG AAG ACG GCG AGG AAG CTT	624
Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu	
195 200 205	

CTG Leu 210	GAG Glu 210	GAG Glu 210	TGG Trp 210	GGG Gly 210	AGC Ser 215	CTG Leu 215	GAA Glu 215	GCC Ala 215	CTC Leu 215	CTC Leu 220	AAG Lys 220	AAC Asn 220	CTG Leu 220	GAC Asp 220	CGG Arg 220	672
CTG Leu 225	AAG Lys 225	CCC Pro 225	GCC Ala 225	ATC Ile 230	CGG Arg 230	GAG Glu 230	AAG Lys 230	ATC Ile 235	CTG Leu 235	GCC Ala 235	CAC His 235	ATG Met 240	GAC Asp 240	GAT Asp 240	CTG Leu 240	720
AAG Lys 245	CTC Leu 245	TCC Ser 245	TGG Trp 245	GAC Asp 245	CTG Leu 245	GCC Ala 245	AAG Lys 250	GTG Val 250	CGC Arg 250	ACC Thr 250	GAC Asp 255	CTG Leu 255	CCC Pro 255	CTG Leu 255	GAG Glu 255	768
GTG Val 260	GAC Asp 260	TTC Phe 260	GCC Ala 260	AAA Lys 260	AGG Arg 265	CGG Arg 265	GAG Glu 265	CCC Pro 265	GAC Asp 265	CGG Arg 270	GAG Glu 270	AGG Arg 270	CTT Leu 270	AGG Arg 270	GCC Ala 270	816
TTT Phe 275	CTG Leu 275	GAG Glu 275	AGG Arg 275	CTT Leu 275	GAG Glu 280	TTT Phe 280	GGC Gly 280	AGC Ser 280	CTC Leu 280	CTC Leu 285	CAC His 285	GAG Glu 285	TTC Phe 285	GGC Gly 285	CTT Leu 285	864
CTG Leu 290	GAA Glu 290	AGC Ser 290	CCC Pro 290	AAG Lys 295	GCC Ala 295	CTG Leu 295	GAG Glu 295	GAG Glu 295	GCC Ala 295	CCC Pro 300	TGG Trp 300	CCC Pro 300	CCG Pro 300	CCG Pro 300	GAA Glu 300	912
GGG Gly 305	GCC Ala 305	TTC Phe 305	GTG Val 310	GGC Gly 310	TTT Phe 310	GTG Val 310	CTT Leu 315	TCC Ser 315	CGC Arg 315	AAG Lys 315	GAG Glu 315	CCC Pro 320	ATG Met 320	TGG Trp 320	GCC Ala 320	960
GAT Asp 325	CTT Leu 325	CTG Leu 325	GCC Ala 325	CTG Leu 325	GCC Ala 325	GCC Ala 325	GCC Ala 330	AGG Arg 330	GGG Gly 330	GGC Gly 330	CGG Arg 335	GTC Val 335	CAC His 335	CGG Arg 335	GCC Ala 335	1008
CCC Pro 340	GAG Glu 340	CCT Pro 340	TAT Tyr 340	AAA Lys 340	GCC Ala 345	CTC Leu 345	AGG Arg 345	GAC Asp 345	CTG Leu 345	AAG Lys 350	GAG Glu 350	GCG Ala 350	CGG Arg 350	GGG Gly 350	CTT Leu 350	1056
CTC Leu 355	GCC Ala 355	AAA Lys 355	GAC Asp 355	CTG Leu 355	AGC Ser 360	GTT Val 360	CTG Leu 360	GCC Ala 360	CTG Leu 365	AGG Arg 365	GAA Glu 365	GGC Gly 365	CTT Leu 365	GGC Gly 365	CTC Leu 365	1104
CCG Pro 370	CCC Pro 370	GGC Gly 370	GAC Asp 375	GAC Asp 375	CCC Pro 375	ATG Met 375	CTC Leu 375	CTC Leu 375	GCC Ala 380	TAC Tyr 380	CTC Leu 380	CTG Leu 380	GAC Asp 380	CCT Pro 380	TCC Ser 380	1152
AAC Asn 385	ACC Thr 385	ACC Thr 385	CCC Pro 390	GAG Glu 390	GGG Gly 390	GTG Val 390	GCC Ala 395	CGG Arg 395	CGC Arg 395	TAC Tyr 395	GGC Gly 395	GGG Gly 400	GAG Glu 400	TGG Trp 400	ACG Thr 400	1200
GAG Glu 405	GAG Glu 405	GCG Ala 405	GGG Gly 405	GAG Glu 405	CGG Arg 410	GCC Ala 410	GCC Ala 410	CTT Leu 410	TCC Ser 410	GAG Glu 415	AGG Arg 415	CTC Leu 415	TTC Phe 415	GCC Ala 415	AAC Asn 415	1248
CTG Leu 420	TGG Trp 420	GGG Gly 420	AGG Arg 420	CTT Leu 420	GAG Glu 425	GGG Gly 425	GAG Glu 425	AGG Arg 425	CTC Leu 425	CTT Leu 430	TGG Trp 430	CTT Leu 430	TAC Tyr 430	CGG Arg 430		1296
GAG Glu 435	GTG Val 435	GAG Glu 435	AGG Arg 435	CCC Pro 440	CTT Leu 440	TCC Ser 440	GCT Ala 440	GTC Val 445	CTG Leu 445	GCC Ala 445	CAC His 445	ATG Met 445	GAG Glu 445	GCC Ala 445	ACG Thr 445	1344
GGG Gly 450	GTG Val 450	CGC Arg 450	CTG Leu 455	GAC Asp 455	GTG Val 455	GCC Ala 455	TAT Tyr 455	CTC Leu 460	AGG Arg 460	GCC Ala 460	TTG Leu 460	TCC Ser 460	CTG Leu 460	GAG Glu 460	GTG Val 460	1392
GCC Ala 465	GAG Glu 465	GAG Glu 465	ATC Ile 470	GCC Ala 470	CGC Arg 470	CTC Leu 470	GAG Glu 475	GCC Ala 475	GAG Glu 475	GTC Val 475	TTC Phe 475	CGC Arg 480	CTG Leu 480	GCC Ala 480	GGC Gly 480	1440

CAC CCC TTC AAC CTC AAC TCC CGG GAC CAG CTG GAA AGG GTC CTC TTT His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe 485 490 495	1488
GAC GAG CTA GGG CTT CCC GCC ATC GGC AAG ACG GAG AAG ACC GGC AAG Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys 500 505 510	1536
CGC TCC ACC AGC GCC GCC GTC CTG GAG GCC CTC CGC GAG GCC CAC CCC Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro 515 520 525	1584
ATC GTG GAG AAG ATC CTG CAG TAC CGG GAG CTC ACC AAG CTG AAG AGC Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser 530 535 540	1632
ACC TAC ATT GAC CCC TTG CCG GAC CTC ATC CAC CCC AGG ACG GGC CGC Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg 545 550 555 560	1680
CTC CAC ACC CGC TTC AAC CAG ACG GCC ACG GCC ACG GGC AGG CTA AGT Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser 565 570 575	1728
AGC TCC GAT CCC AAC CTC CAG AAC ATC CCC GTC CGC ACC CCG CTT GGG Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly 580 585 590	1776
CAG AGG ATC CGC CGG GCC TTC ATC GCC GAG GAG GGG TGG CTA TTG GTG Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val 595 600 605	1824
GCC CTG GAC TAT AGC CAG ATA GAG CTC AGG GTG CTG GCC CAC CTC TCC Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser 610 615 620	1872
GGC GAC GAG AAC CTG ATC CGG GTC TTC CAG GAG GGG CGG GAC ATC CAC Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His 625 630 635 640	1920
ACG GAG ACC GCC AGC TGG ATG TTC GGC GTC CCC CGG GAG GCC GTG GAC Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp 645 650 655	1968
CCC CTG ATG CGC CGG GCG GCC AAG ACC ATC AAC TTC GGG GTC CTC TAC Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr 660 665 670	2016
GGC ATG TCG GCC CAC CGC CTC TCC CAG GAG CTA GCC ATC CCT TAC GAG Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu 675 680 685	2064
GAG GCC CAG GCC TTC ATT GAG CGC TAC TTT CAG AGC TTC CCC AAG GTG Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val 690 695 700	2112
CGG GCC TGG ATT GAG AAG ACC CTG GAG GAG GGC AGG AGG CGG GGG TAC Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr 705 710 715 720	2160
GTG GAG ACC CTC TTC GGC CGC CGC CGC TAC GTG CCA GAC CTA GAG GCC Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala 725 730 735	2208
CGG GTG AAG AGC GTG CGG GAG GCG GCC GAG CGC ATG GCC TTC AAC ATG Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met 740 745 750	2256

CCC GTC CAG GGC ACC GCC GCC GAC CTC ATG AAG CTG GCT ATG GTG AAG Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys 755 760 765	2304
CTC TTC CCC AGG CTG GAG GAA ATG GGG GCC AGG ATG CTC CTT CAG GTC Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val 770 775 780	2352
CAC AAC GAG CTG GTC CTC GAG GCC CCA AAA GAG AGG GCG GAG GCC GTG His Asn Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val 785 790 795 800	2400
GCC CGG CTG GCC AAG GAG GTC ATG GAG GGG GTG TAT CCC CTG GCC GTG Ala Arg Leu Ala Lys Glu Val Met Gly Gly Val Tyr Pro Leu Ala Val 805 810 815	2448
CCC CTG GAG GTG GAG GTG GGG ATA GGG GAG GAC TGG CTC TCC GCC AAG Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys 820 825 830	2496
GAG TGATAG Glu	2505

(2) INFORMATION FOR SEQ ID NO:66:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 833 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:66:

Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu 1 5 10 15
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys 20 25 30
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe 35 40 45
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile 50 55 60
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly 65 70 75 80
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln 85 90 95
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu 100 105 110
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys 115 120 125
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys 130 135 140
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu 145 150 155 160
Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg 165 170 175

Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
 180 185 190
 Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
 195 200 205
 Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
 210 215 220
 Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
 225 230 235 240
 Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
 245 250 255
 Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
 260 265 270
 Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
 275 280 285
 Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
 290 295 300
 Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
 305 310 315 320
 Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
 325 330 335
 Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
 340 345 350
 Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
 355 360 365
 Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
 370 375 380
 Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
 385 390 395 400
 Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
 405 410 415
 Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
 420 425 430
 Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
 435 440 445
 Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
 450 455 460
 Ala Glu Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
 465 470 475 480
 His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
 485 490 495
 Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
 500 505 510
 Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
 515 520 525

Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
 530 535 540
 Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
 545 550 555 560
 Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
 565 570 575
 Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
 580 585 590
 Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
 595 600 605
 Ala Leu Asp Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
 610 615 620
 Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
 625 630 635 640
 Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
 645 650 655
 Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
 660 665 670
 Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
 675 680 685
 Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
 690 695 700
 Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
 705 710 715 720
 Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
 725 730 735
 Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
 740 745 750
 Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
 755 760 765
 Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
 770 775 780
 His Asn Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
 785 790 795 800
 Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
 805 810 815
 Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
 820 825 830
 Glu

(2) INFORMATION FOR SEQ ID NO:67:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 20 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:67:

TGGCTATAGR CCAGGGCCAC

20

(2) INFORMATION FOR SEQ ID NO:68:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 2505 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (ix) FEATURE:
 (A) NAME/KEY: CDS
 (B) LOCATION: 1..2499

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:68:

ATG AAT TCG GGG ATG CTG CCC CTC TTT GAG CCC AAG GGC CGG GTC CTC	48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu	
1 5 10 15	
CTG GTG GAC GGC CAC CAC CTG GCC TAC CGC ACC TTC CAC GCC CTG AAG	96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys	
20 25 30	
GGC CTC ACC ACC AGC CGG GGG GAG CCG GTG CAG GCG GTC TAC GGC TTC	144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe	
35 40 45	
GCC AAG AGC CTC CTC AAG GCC CTC AAG GAG GAC GGG GAC GCG GTG ATC	192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile	
50 55 60	
GTG GTC TTT GAC GCC AAG GCC CCC TCC TTC CGC CAC GAG GCC TAC GGG	240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly	
65 70 75 80	
GGG TAC AAG GCG GGC CGG GCC CCC ACG CCG GAG GAC TTT CCC CGG CAA	288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln	
85 90 95	
CTC GCC CTC ATC AAG GAG CTG GTG GAC CTC CTG GGG CTG GCG CGC CTC	336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu	
100 105 110	
GAG GTC CCG GGC TAC GAG GCG GAC GAC GTC CTG GCC AGC CTG GCC AAG	384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys	
115 120 125	
AAG GCG GAA AAG GAG GGC TAC GAG GTC CGC ATC CTC ACC GCC GAC AAA	432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys	
130 135 140	

GAC CTT TAC CAG CTC CTT TCC GAC CGC ATC CAC GTC CTC CAC CCC GAG Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu 145 150 155 160	480
GGG TAC CTC ATC ACC CCG GCC TGG CTT TGG GAA AAG TAC GGC CTG AGG Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg 165 170 175	528
CCC GAC CAG TGG GCC GAC TAC CGG GCC CTG ACC GGG GAC GAG TCC GAC Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp 180 185 190	576
AAC CTT CCC GGG GTC AAG GGC ATC GGG GAG AAG ACG GCG AGG AAG CTT Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu 195 200 205	624
CTG GAG GAG TGG GGG AGC CTG GAA GCC CTC CTC AAG AAC CTG GAC CGG Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg 210 215 220	672
CTG AAG CCC GCC ATC CGG GAG AAG ATC CTG GCC CAC ATG GAC GAT CTG Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu 225 230 235 240	720
AAG CTC TCC TGG GAC CTG GCC AAG GTG CGC ACC GAC CTG CCC CTG GAG Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu 245 250 255	768
GTG GAC TTC GCC AAA AGG CGG GAG CCC GAC CGG GAG AGG CTT AGG GCC Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala 260 265 270	816
TTT CTG GAG AGG CTT GAG TTT GGC AGC CTC CTC CAC GAG TTC GGC CTT Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu 275 280 285	864
CTG GAA AGC CCC AAG GCC CTG GAG GAG GCC CCC TGG CCC CCG CCG GAA Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu 290 295 300	912
GGG GCC TTC GTG GGC TTT GTG CTT TCC CGC AAG GAG CCC ATG TGG GCC Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala 305 310 315 320	960
GAT CTT CTG GCC CTG GCC GCC GCC AGG GGG GGC CGG GTC CAC CGG GCC Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala 325 330 335	1008
CCC GAG CCT TAT AAA GCC CTC AGG GAC CTG AAG GAG GCG CGG GGG CTT Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu 340 345 350	1056
CTC GCC AAA GAC CTG AGC GTT CTG GCC CTG AGG GAA GGC CTT GGC CTC Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu 355 360 365	1104
CCG CCC GGC GAC GAC CCC ATG CTC CTC GCC TAC CTC CTG GAC CCT TCC Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser 370 375 380	1152
AAC ACC ACC CCC GAG GGG GTG GCC CGG CGC TAC GGC GGG GAG TGG ACG Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr 385 390 395 400	1200
GAG GAG GCG GGG GAG CGG GCC GCC CTT TCC GAG AGG CTC TTC GCC AAC Glu Glu Ala Gly Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn 405 410 415	1248

CTG TGG GGG AGG CTT GAG GGG GAG GAG AGG CTC CTT TGG CTT TAC CGG Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg	1296
420 425 430	
GAG GTG GAG AGG CCC CTT TCC GCT GTC CTG GCC CAC ATG GAG GCC ACG Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr	1344
435 440 445	
GGG GTG CGC CTG GAC GTG GCC TAT CTC AGG GCC TTG TCC CTG GAG GTG Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val	1392
450 455 460	
GCC GGG GAG ATC GCC CGC CTC GAG GCC GAG GTC TTC CGC CTG GCC GGC Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly	1440
465 470 475 480	
CAC CCC TTC AAC CTC AAC TCC CGG GAC CAG CTG GAA AGG GTC CTC TTT His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe	1488
485 490 495	
GAC GAG CTA GGG CTT CCC GCC ATC GGC AAG ACG GAG AAG ACC GGC AAG Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys	1536
500 505 510	
CGC TCC ACC AGC GCC GCC GTC CTG GAG GCC CTC CGC GAG GCC CAC CCC Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro	1584
515 520 525	
ATC GTG GAG AAG ATC CTG CAG TAC CGG GAG CTC ACC AAG CTG AAG AGC Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser	1632
530 535 540	
ACC TAC ATT GAC CCC TTG CCG GAC CTC ATC CAC CCC AGG ACG GGC CGC Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg	1680
545 550 555 560	
CTC CAC ACC CGC TTC AAC CAG ACG GCC ACG GCC ACG GGC AGG CTA AGT Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser	1728
565 570 575	
AGC TCC GAT CCC AAC CTC CAG AAC ATC CCC GTC CGC ACC CCG CTT GGG Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly	1776
580 585 590	
CAG AGG ATC CGC CGG GCC TTC ATC GCC GAG GAG GGG TGG CTA TTG GTG Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val	1824
595 600 605	
GCC CTG GCC TAT AGC CAG ATA GAG CTC AGG GTG CTG GCC CAC CTC TCC Ala Leu Ala Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser	1872
610 615 620	
GGC GAC GAG AAC CTG ATC CGG GTC TTC CAG GAG GGG CGG GAC ATC CAC Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His	1920
625 630 635 640	
ACG GAG ACC GCC AGC TGG ATG TTC GGC GTC CCC CGG GAG GCC GTG GAC Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp	1968
645 650 655	
CCC CTG ATG CGC CGG GCG GCC AAG ACC ATC AAC TTC GGG GTC CTC TAC Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr	2016
660 665 670	
GGC ATG TCG GCC CAC CGC CTC TCC CAG GAG CTA GCC ATC CCT TAC GAG Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu	2064
675 680 685	

GAG GCC CAG GCC TTC ATT GAG CGC TAC TTT CAG AGC TTC CCC AAG GTG Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val 690 695 700	2112
CGG GCC TGG ATT GAG AAG ACC CTG GAG GAG GGC AGG AGG CGG GGG TAC Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr 705 710 715 720	2160
GTG GAG ACC CTC TTC GGC CGC CGC CGC TAC GTG CCA GAC CTA GAG GCC Val Glu Thr Leu Phe Gly Arg Arg Tyr Val Pro Asp Leu Glu Ala 725 730 735	2208
CGG GTG AAG AGC GTG CGG GAG GCG GCC GAG CGC ATG GCC TTC AAC ATG Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met 740 745 750	2256
CCC GTC CAG GGC ACC GCC GCC GAC CTC ATG AAG CTG GCT ATG GTG AAG Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys 755 760 765	2304
CTC TTC CCC AGG CTG GAG GAA ATG GGG GCC AGG ATG CTC CTT CAG GTC Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val 770 775 780	2352
CAC GAC GAG CTG GTC CTC GAG GCC CCA AAA GAG AGG GCG GAG GCC GTG His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val 785 790 795 800	2400
GCC CGG CTG GCC AAG GAG GTC ATG GAG GGG GTG TAT CCC CTG GCC GTG Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val 805 810 815	2448
CCC CTG GAG GTG GAG GTG GGG ATA GGG GAG GAC TGG CTC TCC GCC AAG Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys 820 825 830	2496
GAG TGATAG Glu	2505

(2) INFORMATION FOR SEQ ID NO:69:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 833 amino acids
 - (B) TYPE: amino acid
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:69:

Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu 1 5 10 15
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys 20 25 30
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe 35 40 45
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile 50 55 60
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly 65 70 75 80
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln 85 90 95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
 100 105 110
 Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
 115 120 125
 Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
 130 135 140
 Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
 145 150 155 160
 Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
 165 170 175
 Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
 180 185 190
 Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
 195 200 205
 Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
 210 215 220
 Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
 225 230 235 240
 Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
 245 250 255
 Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
 260 265 270
 Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
 275 280 285
 Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
 290 295 300
 Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
 305 310 315 320
 Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
 325 330 335
 Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
 340 345 350
 Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
 355 360 365
 Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
 370 375 380
 Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
 385 390 395 400
 Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
 405 410 415
 Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
 420 425 430
 Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
 435 440 445

Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
 450 455 460
 Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
 465 470 475 480
 His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
 485 490 495
 Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
 500 505 510
 Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
 515 520 525
 Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
 530 535 540
 Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
 545 550 555 560
 Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
 565 570 575
 Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
 580 585 590
 Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
 595 600 605
 Ala Leu Ala Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
 610 615 620
 Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
 625 630 635 640
 Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
 645 650 655
 Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
 660 665 670
 Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
 675 680 685
 Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
 690 695 700
 Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
 705 710 715 720
 Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
 725 730 735
 Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
 740 745 750
 Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
 755 760 765
 Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
 770 775 780
 His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
 785 790 795 800

Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
 805 810 815

Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
 820 825 830

Glu

(2) INFORMATION FOR SEQ ID NO:70:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 2505 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..2499

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:70:

ATG AAT TCG GGG ATG CTG CCC CTC TTT GAG CCC AAG GGC CGG GTC CTC	48
Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu	
1 5 10 15	
CTG GTG GAC GGC CAC CAC CTG GCC TAC CGC ACC TTC CAC GCC CTG AAG	96
Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys	
20 25 30	
GGC CTC ACC ACC AGC CGG GGG GAG CCG GTG CAG GCG GTC TAC GGC TTC	144
Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe	
35 40 45	
GCC AAG AGC CTC CTC AAG GCC CTC AAG GAG GAC GGG GAC GCG GTG ATC	192
Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile	
50 55 60	
GTG GTC TTT GAC GCC AAG GCC CCC TCC TTC CGC CAC GAG GCC TAC GGG	240
Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly	
65 70 75 80	
GGG TAC AAG GCG GGC CGG GCC CCC ACG CCG GAG GAC TTT CCC CGG CAA	288
Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln	
85 90 95	
CTC GCC CTC ATC AAG GAG CTG GTG GAC CTC CTG GGG CTG GCG CGC CTC	336
Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu	
100 105 110	
GAG GTC CCG GGC TAC GAG GCG GAC GAC GTC CTG GCC AGC CTG GCC AAG	384
Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys	
115 120 125	
AAG GCG GAA AAG GAG GGC TAC GAG GTC CGC ATC CTC ACC GCC GAC AAA	432
Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys	
130 135 140	
GAC CTT TAC CAG CTC CTT TCC GAC CGC ATC CAC GTC CTC CAC CCC GAG	480
Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu	
145 150 155 160	

GGG TAC CTC ATC ACC CCG GCC TGG CTT TGG GAA AAG TAC GGC CTG AGG Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg 165 170 175	528
CCC GAC CAG TGG GCC GAC TAC CGG GCC CTG ACC GGG GAC GAG TCC GAC Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp 180 185 190	576
AAC CTT CCC GGG GTC AAG GGC ATC GGG GAG AAG ACG GCG AGG AAG CTT Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu 195 200 205	624
CTG GAG GAG TGG GGG AGC CTG GAA GCC CTC CTC AAG AAC CTG GAC CGG Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg 210 215 220	672
CTG AAG CCC GCC ATC CGG GAG AAG ATC CTG GCC CAC ATG GAC GAT CTG Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu 225 230 235 240	720
AAG CTC TCC TGG GAC CTG GCC AAG GTG CGC ACC GAC CTG CCC CTG GAG Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu 245 250 255	768
GTG GAC TTC GCC AAA AGG CGG GAG CCC GAC CGG GAG AGG CTT AGG GCC Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala 260 265 270	816
TTT CTG GAG AGG CTT GAG TTT GGC AGC CTC CTC CAC GAG TTC GGC CTT Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu 275 280 285	864
CTG GAA AGC CCC AAG GCC CTG GAG GAG GCC CCC TGG CCC CCG CCG GAA Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu 290 295 300	912
GGG GCC TTC GTG GGC TTT GTG CTT TCC CGC AAG GAG CCC ATG TGG GCC Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala 305 310 315 320	960
GAT CTT CTG GCC CTG GCC GCC GCC AGG GGG GGC CGG GTC CAC CGG GCC Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala 325 330 335	1008
CCC GAG CCT TAT AAA GCC CTC AGG GAC CTG AAG GAG GCG CGG GGG CTT Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu 340 345 350	1056
CTC GCC AAA GAC CTG AGC GTT CTG GCC CTG AGG GAA GGC CTT GGC CTC Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu 355 360 365	1104
CCG CCC GGC GAC GAC CCC ATG CTC CTC GCC TAC CTC CTG GAC CCT TCC Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser 370 375 380	1152
AAC ACC ACC CCC GAG GGG GTG GCC CGG CGC TAC GGC GGG GAG TGG ACG Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr 385 390 395 400	1200
GAG GAG GCG GGG GAG CGG GCC GCC CTT TCC GAG AGG CTC TTC GCC AAC Glu Glu Ala Gly Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn 405 410 415	1248
CTG TGG GGG AGG CTT GAG GGG GAG GAG AGG CTC CTT TGG CTT TAC CGG Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Tyr Arg 420 425 430	1296

GAG GTG GAG AGG CCC CTT TCC GCT GTC CTG GCC CAC ATG GAG GCC ACG Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr	1344
435 440 445	
GGG GTG CGC CTG GAC GTG GCC TAT CTC AGG GCC TTG TCC CTG GAG GTG Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val	1392
450 455 460	
GCC GGG GAG ATC GCC CGC CTC GAG GCC GAG GTC TTC CGC CTG GCC GGC Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly	1440
465 470 475 480	
CAC CCC TTC AAC CTC AAC TCC CGG GAC CAG CTG GAA AGG GTC CTC TTT His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe	1488
485 490 495	
GAC GAG CTA GGG CTT CCC GCC ATC GGC AAG ACG GAG AAG ACC GGC AAG Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys	1536
500 505 510	
CGC TCC ACC AGC GCC GCC GTC CTG GAG GCC CTC CGC GAG GCC CAC CCC Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro	1584
515 520 525	
ATC GTG GAG AAG ATC CTG CAG TAC CGG GAG CTC ACC AAG CTG AAG AGC Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser	1632
530 535 540	
ACC TAC ATT GAC CCC TTG CCG GAC CTC ATC CAC CCC AGG ACG GGC CGC Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg	1680
545 550 555 560	
CTC CAC ACC CGC TTC AAC CAG ACG GCC ACG GCC ACG GGC AGG CTA AGT Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser	1728
565 570 575	
AGC TCC GAT CCC AAC CTC CAG AAC ATC CCC GTC CGC ACC CCG CTT GGG Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly	1776
580 585 590	
CAG AGG ATC CGC CGG GCC TTC ATC GCC GAG GAG GGG TGG CTA TTG GTG Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val	1824
595 600 605	
GCC CTG GTC TAT AGC CAG ATA GAG CTC AGG GTG CTG GCC CAC CTC TCC Ala Leu Val Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser	1872
610 615 620	
GGC GAC GAG AAC CTG ATC CGG GTC TTC CAG GAG GGG CGG GAC ATC CAC Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His	1920
625 630 635 640	
ACG GAG ACC GCC AGC TGG ATG TTC GGC GTC CCC CGG GAG GCC GTG GAC Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp	1968
645 650 655	
CCC CTG ATG CGC CGG GCG GCC AAG ACC ATC AAC TTC GGG GTC CTC TAC Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr	2016
660 665 670	
GGC ATG TCG GCC CAC CGC CTC TCC CAG GAG CTA GCC ATC CCT TAC GAG Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu	2064
675 680 685	
GAG GCC CAG GCC TTC ATT GAG CGC TAC TTT CAG AGC TTC CCC AAG GTG Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val	2112
690 695 700	

CGG GCC TGG ATT GAG AAG ACC CTG GAG GAG GGC AGG AGG CGG GGG TAC Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr 705 710 715 720	2160
GTG GAG ACC CTC TTC GGC CGC CGC CGC TAC GTG CCA GAC CTA GAG GCC Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala 725 730 735	2208
CGG GTG AAG AGC GTG CGG GAG GCG GCC GAG CGC ATG GCC TTC AAC ATG Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met 740 745 750	2256
CCC GTC CAG GGC ACC GCC GCC GAC CTC ATG AAG CTG GCT ATG GTG AAG Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys 755 760 765	2304
CTC TTC CCC AGG CTG GAG GAA ATG GGG GCC AGG ATG CTC CTT CAG GTC Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val 770 775 780	2352
CAC GAC GAG CTG GTC CTC GAG GCC CCA AAA GAG AGG GCG GAG GCC GTG His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val 785 790 795 800	2400
GCC CGG CTG GCC AAG GAG GTC ATG GAG GGG GTG TAT CCC CTG GCC GTG Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val 805 810 815	2448
CCC CTG GAG GTG GAG GTG GGG ATA GGG GAG GAC TGG CTC TCC GCC AAG Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys 820 825 830	2496
GAG TGATAG Glu	2505

(2) INFORMATION FOR SEQ ID NO:71:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 833 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:71:

Met Asn Ser Gly Met Leu Pro Leu Phe Glu Pro Lys Gly Arg Val Leu
1 5 10 15

Leu Val Asp Gly His His Leu Ala Tyr Arg Thr Phe His Ala Leu Lys
20 25 30

Gly Leu Thr Thr Ser Arg Gly Glu Pro Val Gln Ala Val Tyr Gly Phe
35 40 45

Ala Lys Ser Leu Leu Lys Ala Leu Lys Glu Asp Gly Asp Ala Val Ile
50 55 60

Val Val Phe Asp Ala Lys Ala Pro Ser Phe Arg His Glu Ala Tyr Gly
65 70 75 80

Gly Tyr Lys Ala Gly Arg Ala Pro Thr Pro Glu Asp Phe Pro Arg Gln
85 90 95

Leu Ala Leu Ile Lys Glu Leu Val Asp Leu Leu Gly Leu Ala Arg Leu
100 105 110

Glu Val Pro Gly Tyr Glu Ala Asp Asp Val Leu Ala Ser Leu Ala Lys
 115 120 125
 Lys Ala Glu Lys Glu Gly Tyr Glu Val Arg Ile Leu Thr Ala Asp Lys
 130 135 140
 Asp Leu Tyr Gln Leu Leu Ser Asp Arg Ile His Val Leu His Pro Glu
 145 150 155 160
 Gly Tyr Leu Ile Thr Pro Ala Trp Leu Trp Glu Lys Tyr Gly Leu Arg
 165 170 175
 Pro Asp Gln Trp Ala Asp Tyr Arg Ala Leu Thr Gly Asp Glu Ser Asp
 180 185 190
 Asn Leu Pro Gly Val Lys Gly Ile Gly Glu Lys Thr Ala Arg Lys Leu
 195 200 205
 Leu Glu Glu Trp Gly Ser Leu Glu Ala Leu Leu Lys Asn Leu Asp Arg
 210 215 220
 Leu Lys Pro Ala Ile Arg Glu Lys Ile Leu Ala His Met Asp Asp Leu
 225 230 235 240
 Lys Leu Ser Trp Asp Leu Ala Lys Val Arg Thr Asp Leu Pro Leu Glu
 245 250 255
 Val Asp Phe Ala Lys Arg Arg Glu Pro Asp Arg Glu Arg Leu Arg Ala
 260 265 270
 Phe Leu Glu Arg Leu Glu Phe Gly Ser Leu Leu His Glu Phe Gly Leu
 275 280 285
 Leu Glu Ser Pro Lys Ala Leu Glu Glu Ala Pro Trp Pro Pro Pro Glu
 290 295 300
 Gly Ala Phe Val Gly Phe Val Leu Ser Arg Lys Glu Pro Met Trp Ala
 305 310 315 320
 Asp Leu Leu Ala Leu Ala Ala Ala Arg Gly Gly Arg Val His Arg Ala
 325 330 335
 Pro Glu Pro Tyr Lys Ala Leu Arg Asp Leu Lys Glu Ala Arg Gly Leu
 340 345 350
 Leu Ala Lys Asp Leu Ser Val Leu Ala Leu Arg Glu Gly Leu Gly Leu
 355 360 365
 Pro Pro Gly Asp Asp Pro Met Leu Leu Ala Tyr Leu Leu Asp Pro Ser
 370 375 380
 Asn Thr Thr Pro Glu Gly Val Ala Arg Arg Tyr Gly Gly Glu Trp Thr
 385 390 395 400
 Glu Glu Ala Gly Glu Arg Ala Ala Leu Ser Glu Arg Leu Phe Ala Asn
 405 410 415
 Leu Trp Gly Arg Leu Glu Gly Glu Glu Arg Leu Leu Trp Leu Tyr Arg
 420 425 430
 Glu Val Glu Arg Pro Leu Ser Ala Val Leu Ala His Met Glu Ala Thr
 435 440 445
 Gly Val Arg Leu Asp Val Ala Tyr Leu Arg Ala Leu Ser Leu Glu Val
 450 455 460

Ala Gly Glu Ile Ala Arg Leu Glu Ala Glu Val Phe Arg Leu Ala Gly
 465 470 475 480
 His Pro Phe Asn Leu Asn Ser Arg Asp Gln Leu Glu Arg Val Leu Phe
 485 490 495
 Asp Glu Leu Gly Leu Pro Ala Ile Gly Lys Thr Glu Lys Thr Gly Lys
 500 505 510
 Arg Ser Thr Ser Ala Ala Val Leu Glu Ala Leu Arg Glu Ala His Pro
 515 520 525
 Ile Val Glu Lys Ile Leu Gln Tyr Arg Glu Leu Thr Lys Leu Lys Ser
 530 535 540
 Thr Tyr Ile Asp Pro Leu Pro Asp Leu Ile His Pro Arg Thr Gly Arg
 545 550 555 560
 Leu His Thr Arg Phe Asn Gln Thr Ala Thr Ala Thr Gly Arg Leu Ser
 565 570 575
 Ser Ser Asp Pro Asn Leu Gln Asn Ile Pro Val Arg Thr Pro Leu Gly
 580 585 590
 Gln Arg Ile Arg Arg Ala Phe Ile Ala Glu Glu Gly Trp Leu Leu Val
 595 600 605
 Ala Leu Val Tyr Ser Gln Ile Glu Leu Arg Val Leu Ala His Leu Ser
 610 615 620
 Gly Asp Glu Asn Leu Ile Arg Val Phe Gln Glu Gly Arg Asp Ile His
 625 630 635 640
 Thr Glu Thr Ala Ser Trp Met Phe Gly Val Pro Arg Glu Ala Val Asp
 645 650 655
 Pro Leu Met Arg Arg Ala Ala Lys Thr Ile Asn Phe Gly Val Leu Tyr
 660 665 670
 Gly Met Ser Ala His Arg Leu Ser Gln Glu Leu Ala Ile Pro Tyr Glu
 675 680 685
 Glu Ala Gln Ala Phe Ile Glu Arg Tyr Phe Gln Ser Phe Pro Lys Val
 690 695 700
 Arg Ala Trp Ile Glu Lys Thr Leu Glu Glu Gly Arg Arg Arg Gly Tyr
 705 710 715 720
 Val Glu Thr Leu Phe Gly Arg Arg Arg Tyr Val Pro Asp Leu Glu Ala
 725 730 735
 Arg Val Lys Ser Val Arg Glu Ala Ala Glu Arg Met Ala Phe Asn Met
 740 745 750
 Pro Val Gln Gly Thr Ala Ala Asp Leu Met Lys Leu Ala Met Val Lys
 755 760 765
 Leu Phe Pro Arg Leu Glu Glu Met Gly Ala Arg Met Leu Leu Gln Val
 770 775 780
 His Asp Glu Leu Val Leu Glu Ala Pro Lys Glu Arg Ala Glu Ala Val
 785 790 795 800
 Ala Arg Leu Ala Lys Glu Val Met Glu Gly Val Tyr Pro Leu Ala Val
 805 810 815

Pro Leu Glu Val Glu Val Gly Ile Gly Glu Asp Trp Leu Ser Ala Lys
 820 825 830

Glu

(2) INFORMATION FOR SEQ ID NO:72:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 25 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:72:

GGGATACCAT GGGAGTGCAG TTTGG

25

(2) INFORMATION FOR SEQ ID NO:73:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 27 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:73:

GGTAAATTTT TCTCGTCGAC ATCCAC

27

(2) INFORMATION FOR SEQ ID NO:74:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 981 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)

- (ix) FEATURE:
 (A) NAME/KEY: CDS
 (B) LOCATION: 1..978

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:74:

ATG GGA GTG CAG TTT GGT GAT TTT ATT CCA AAA AAT ATT ATC TCC TTT
 Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
 1 5 10 15

48

GAA GAT TTA AAA GGG AAA AAA GTA GCT ATT GAT GGA ATG AAT GCA TTA
 Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
 20 25 30

96

TAT CAG TTT TTA ACA TCT ATA CGT TTG AGA GAT GGT TCT CCA TTG AGA
 Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
 35 40 45

144

AAT AGA AAA GGA GAG ATA ACC TCA GCA TAT AAC GGA GTT TTT TAT AAA
 Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
 50 55 60

192

ACC ATA CAT TTG TTA GAG AAT GAT ATA ACT CCA ATC TGG GTT TTT GAT Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp 65 70 75 80	240
GGT GAG CCA CCA AAG TTA AAG GAG AAA ACA AGG AAA GTT AGG AGA GAG Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu 85 90 95	288
ATG AAA GAG AAA GCT GAA CTT AAG ATG AAA GAG GCA ATT AAA AAG GAG Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu 100 105 110	336
GAT TTT GAA GAA GCT GCT AAG TAT GCA AAG AGG GTT AGC TAT CTA ACT Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr 115 120 125	384
CCG AAA ATG GTT GAA AAC TGC AAA TAT TTG TTA AGT TTG ATG GGC ATT Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile 130 135 140	432
CCG TAT GTT GAA GCT CCC TCT GAG GGA GAG GCA CAA GCA AGC TAT ATG Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met 145 150 155 160	480
GCA AAG AAG GGA GAT GTT TGG GCA GTT GTA AGT CAA GAT TAT GAT GCC Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala 165 170 175	528
TTG TTA TAT GGA GCT CCG AGA GTT GTT AGA AAT TTA ACA ACT ACA AAG Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Lys 180 185 190	576
GAG ATG CCA GAA CTT ATT GAA TTA AAT GAG GTT TTA GAG GAT TTA AGA Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg 195 200 205	624
ATT TCT TTG GAT GAT TTG ATA GAT ATA GCC ATA TTT ATG GGA ACT GAC Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp 210 215 220	672
TAT AAT CCA GGA GGA GTT AAA GGA ATA GGA TTT AAA AGG GCT TAT GAA Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu 225 230 235 240	720
TTG GTT AGA AGT GGT GTA GCT AAG GAT GTT TTG AAA AAA GAG GTT GAA Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu 245 250 255	768
TAC TAC GAT GAG ATT AAG AGG ATA TTT AAA GAG CCA AAG GTT ACC GAT Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp 260 265 270	816
AAC TAT TCA TTA AGC CTA AAA TTG CCA GAT AAA GAG GGA ATT ATA AAA Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys 275 280 285	864
TTC TTA GTT GAT GAA AAT GAC TTT AAT TAT GAT AGG GTT AAA AAG CAT Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His 290 295 300	912
GTT GAT AAA CTC TAT AAC TTA ATT GCA AAC AAA ACT AAG CAA AAA ACA Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr 305 310 315 320	960
TTA GAT GCA TGG TTT AAA TAA Leu Asp Ala Trp Phe Lys 325	981

(2) INFORMATION FOR SEQ ID NO:75:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 326 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:75:

```

Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
 1           5           10           15
Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
 20           25           30
Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
 35           40           45
Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
 50           55           60
Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp
 65           70           75           80
Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu
 85           90           95
Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu
100           105           110
Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr
115           120           125
Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile
130           135           140
Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met
145           150           155           160
Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala
165           170           175
Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Thr Lys
180           185           190
Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg
195           200           205
Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp
210           215           220
Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu
225           230           235           240
Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu
245           250           255
Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp
260           265           270
Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys
275           280           285
Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His
290           295           300

```

Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr
 305 310 315 320

Leu Asp Ala Trp Phe Lys
 325

(2) INFORMATION FOR SEQ ID NO:76:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:76:

GAGGTGATAC CATGGGTGTC C

21

(2) INFORMATION FOR SEQ ID NO:77:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 20 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:77:

GAAACTCTGC AGCGCGTCAG

20

(2) INFORMATION FOR SEQ ID NO:78:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1023 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: double
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..1020

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:78:

ATG GGT GTC CCA ATT GGT GAG ATT ATA CCA AGA AAA GAA ATT GAG TTA
 Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
 1 5 10 15

48

GAA AAC CTA TAC GGG AAA AAA ATC GCA ATC GAC GCT CTT AAT GCA ATC
 Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
 20 25 30

96

TAC CAA TTT TTG TCC ACA ATA AGA CAG AAA GAT GGA ACT CCA CTT ATG
 Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
 35 40 45

144

GAT TCA AAG GGT AGA ATA ACC TCC CAC CTA AGC GGG CTC TTT TAC AGG
 Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
 50 55 60

192

ACA ATA AAC CTA ATG GAG GCT GGA ATA AAA CCT GTG TAT GTT TTT GAT Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp 65 70 75 80	240
GGA GAA CCT CCA GAA TTC AAA AAG AAA GAG CTC GAA AAA AGA AGA GAA Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu 85 90 95	288
GCG AGA GAG GAA GCT GAA GAA AAG TGG AGA GAA GCA CTT GAA AAA GGA Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly 100 105 110	336
GAG ATA GAG GAA GCA AGA AAA TAT GCC CAA AGA GCA ACC AGG GTA AAT Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn 115 120 125	384
GAA ATG CTC ATC GAG GAT GCA AAA AAA CTC TTA GAG CTT ATG GGA ATT Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile 130 135 140	432
CCT ATA GTT CAA GCA CCT AGC GAG GGA GAG GCC CAA GCT GCA TAT ATG Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met 145 150 155 160	480
GCC GCA AAG GGG AGC GTG TAT GCA TCG GCT AGT CAA GAT TAC GAT TCC Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser 165 170 175	528
CTA CTT TTT GGA GCT CCA AGA CTT GTT AGA AAC TTA ACA ATA ACA GGA Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly 180 185 190	576
AAA AGA AAG TTG CCT GGG AAA AAT GTC TAC GTC GAG ATA AAG CCC GAG Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu 195 200 205	624
TTG ATA ATT TTG GAG GAA GTA CTC AAG GAA TTA AAG CTA ACA AGA GAA Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu 210 215 220	672
AAG CTC ATT GAA CTA GCA ATC CTC GTT GGA ACA GAC TAC AAC CCA GGA Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly 225 230 235 240	720
GGA ATA AAG GGC ATA GGC CTT AAA AAA GCT TTA GAG ATT GTT AGA CAC Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His 245 250 255	768
TCA AAA GAT CCG CTA GCA AAG TTC CAA AAG CAA AGC GAT GTG GAT TTA Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu 260 265 270	816
TAT GCA ATA AAA GAG TTC TTC CTA AAC CCA CCA GTC ACA GAT AAC TAC Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr 275 280 285	864
AAT TTA GTG TGG AGA GAT CCC GAC GAA GAG GGA ATA CTA AAG TTC TTA Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu 290 295 300	912
TGT GAC GAG CAT GAC TTT AGT GAG GAA AGA GTA AAG AAT GGA TTA GAG Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu 305 310 315 320	960

AGG CTT AAG AAG GCA ATC AAA AGT GGA AAA CAA TCA ACC CTT GAA AGT 1008
 Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser 335

TGG TTC AAG AGA TAA
 Trp Phe Lys Arg 1023
 340

(2) INFORMATION FOR SEQ ID NO:79:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 340 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:79:

Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
 1 5 10 15
 Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
 20 25 30
 Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
 35 40 45
 Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
 50 55 60
 Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp
 65 70 75 80
 Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu
 85 90 95
 Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly
 100 105 110
 Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn
 115 120 125
 Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
 130 135 140
 Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
 145 150 155 160
 Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
 165 170 175
 Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
 180 185 190
 Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu
 195 200 205
 Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu
 210 215 220
 Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
 225 230 235 240
 Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His
 245 250 255

Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu
 260 265 270
 Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr
 275 280 285
 Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
 290 295 300
 Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
 305 310 315 320
 Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser
 325 330 335
 Trp Phe Lys Arg
 340

(2) INFORMATION FOR SEQ ID NO:80:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 25 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:80:

GATACCATGG GTGTCCCAAT TGGTG

25

(2) INFORMATION FOR SEQ ID NO:81:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 37 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:81:

TCGACGTCGA CTTATCTCTT GAACCAACTT TCAAGGG

37

(2) INFORMATION FOR SEQ ID NO:82:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 20 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:82:

AGCGAGGGAG AGGCCCAAGC

20

(2) INFORMATION FOR SEQ ID NO:83:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 21 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:83:

GCCTATGCCC TTTATTCCTC C

21

(2) INFORMATION FOR SEQ ID NO:84:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 33 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:84:

TGGTCGCTGT CTCGCTGAAA GCGAGACAGC GTG

33

(2) INFORMATION FOR SEQ ID NO:85:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:85:

TGCTCTCTGG TCGCTGTCTG AAAGACAGCG

30

(2) INFORMATION FOR SEQ ID NO:86:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 27 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer containing a fluorescein label."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:86:

NAGAAAGGAA GGGAAGAAAG CGAAAGG

27

(2) INFORMATION FOR SEQ ID NO:87:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 28 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(27, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 dye."
- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 28
 - (D) OTHER INFORMATION: /mod_base= OTHER

/note= "The residue at this position is a dideoxycytidine."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:87:

AGAAAGGAAG GGAAGAAAGC GAAAGGNC

28

(2) INFORMATION FOR SEQ ID NO:88:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 24 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 24
 - (D) OTHER INFORMATION: /mod_base= OTHER

/note= "The residue at this position is a dideoxycytidine."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:88:

GCCGGCGAAC GTGGCGAGAA AGGC

24

(2) INFORMATION FOR SEQ ID NO:89:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 29 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer containing a fluorescein label."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(28, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 dye."

(ix) FEATURE:
 (A) NAME/KEY: modified_base
 (B) LOCATION: 29
 (D) OTHER INFORMATION: /mod_base= OTHER
/note= "The residue at this position is a dideoxycytidine."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:89:

NAGAAAGGAA GGGAAGAAAG CGAAAGGNC

29

(2) INFORMATION FOR SEQ ID NO:90:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 30 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:90:

AAAATTCCTT TCTCTTGCC CTTTGCTTCC

30

(2) INFORMATION FOR SEQ ID NO:91:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 26 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:91:

GGAAAGCCGG CGAACGTGGC GAGAAA

26

(2) INFORMATION FOR SEQ ID NO:92:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 24 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:92:

GGAAAGCCGG CGAACGTGGC GAGA

24

(2) INFORMATION FOR SEQ ID NO:93:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 29 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 dye."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(28, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a biotin group."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:93:

NAGAAAGGAA GGAAGAAAG CGAAGGNT

29

(2) INFORMATION FOR SEQ ID NO:94:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 25 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 dye."
- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 2..3
 - (D) OTHER INFORMATION: /mod_base= OTHER

/note= "The residues at these positions have an amino group added."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(24, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer containing a fluorescein label."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:94:

NTCCAGAGC CTAATTGCC AGTNA

25

(2) INFORMATION FOR SEQ ID NO:95:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 24 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (ix) FEATURE:
 - (A) NAME/KEY: modified_base
 - (B) LOCATION: 1
 - (D) OTHER INFORMATION: /mod_base= OTHER

/note= "The residue at this position has a 5' TET-label."

- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(23, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer containing a fluorescein label."

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:95:

TTCCAGAGCC TAATTGCCA GTNA

24

(2) INFORMATION FOR SEQ ID NO:96:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 25 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:96:

CTTACCAACG CTAACGAGCG TCTTG

25

(2) INFORMATION FOR SEQ ID NO:97:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 43 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:97:

CCCGTCTCGC TGGTGAAAAG AAAAACCACC CTGGCGCCCA ATA

43

(2) INFORMATION FOR SEQ ID NO:98:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 23 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:98:
TATTGGGCGC CATGGTGGTT TTT 23

(2) INFORMATION FOR SEQ ID NO:99:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(10, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 5-nitroindole."

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(16, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 5-nitroindole."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:99:
TATTGGGCGN CAGGGNGGTT TTT 23

(2) INFORMATION FOR SEQ ID NO:100:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(10, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 5-nitroindole."

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(16, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 5-nitroindole."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:100:
TATTGGGCGN CATGGNGGTT TTT 23

(2) INFORMATION FOR SEQ ID NO:101:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 23 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(16, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 3-nitropyrrole."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:101:

TATTGGGCGC CAGGGNGGTT TTT

23

(2) INFORMATION FOR SEQ ID NO:102:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 23 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(16, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 3-nitropyrrole group."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:102:

TATTGGGCGC CATGGNGGTT TTT

23

(2) INFORMATION FOR SEQ ID NO:103:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 56 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyctosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(2, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(3, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(4..5, "")
 (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(6, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(7, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(8, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(9..10, "")
 (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:103:

CTGAATATAA ACTTGTGGTA GTTGGAGCTG GTGCCGTAGG CAAGAGTGCC TTGACG

56

(2) INFORMATION FOR SEQ ID NO:104:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 56 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(1, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(2, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(3, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(4..5, "")
 (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(6, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(7, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(8, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(9..10, "")
 (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:104:

CTGAATATAA ACTTGTGGTA GTTGAGCTG GTGACGTAGG CAAGAGTGCC TTGACG

56

(2) INFORMATION FOR SEQ ID NO:105:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 23 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(1, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(2, "")
 (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyctosine 5'-O-(1-Thiomonophosphate)."

- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(3, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(4, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(5..6, "")
(D) OTHER INFORMATION: /note= "The residues at these positions are 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(7..8, "")
(D) OTHER INFORMATION: /note= "The residues at these positions are 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(9, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:105:

GCTCAAGGCA CTCTTGCCTA CGA

23

(2) INFORMATION FOR SEQ ID NO:106:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 9 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(1, "")
(D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 amidite label."
- (ix) FEATURE:
(A) NAME/KEY: modified_base
(B) LOCATION: 2..3
(D) OTHER INFORMATION: /mod_base= OTHER
/note= "The residues at these positions have an amino group added."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:106:

NTTCACCAG

9

(2) INFORMATION FOR SEQ ID NO:107:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 27 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(2, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(3..4, "")
 - (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(5..6, "")
 - (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(7, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(8, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(9, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:107:

CTCCAACCTAC CACAAGTTTA TATTCAG

27

(2) INFORMATION FOR SEQ ID NO:108:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 14 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:108:

CGAGAGACCA CGCT

14

(2) INFORMATION FOR SEQ ID NO:109:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 14 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(14, "")
(D) OTHER INFORMATION: /note= "The residue at this
positions contain an abasic ribose."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:109:

CGAGAGACCA CGCT

14

(2) INFORMATION FOR SEQ ID NO:110:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 14 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(14, "")
(D) OTHER INFORMATION: /note= "The residue at this
position contains an abasic ribose with a 3' phosphate group."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:110:

CGAGAGACCA CGCT

14

(2) INFORMATION FOR SEQ ID NO:111:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 15 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
(A) NAME/KEY: misc_difference
(B) LOCATION: replace(15, "")
(D) OTHER INFORMATION: /note= "The residue at this
position contains a 3' phosphate group."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:111:

CGAGAGACCA CGCTG

15

(2) INFORMATION FOR SEQ ID NO:112:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid

- (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(1, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(2, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(3..4, "")

(D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(5, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(6, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(7..8, "")

(D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(9, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."

(ix) FEATURE:

- (A) NAME/KEY: misc_difference

- (B) LOCATION: replace(10, "")

(D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxycytosine 5'-O-(1-Thiomonophosphate)."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:112:

GTAATCTTAC CAACGCTAAC GAGCGTCTTG

30

(2) INFORMATION FOR SEQ ID NO:113:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 31 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1..2, "")
 - (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyctosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(3, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(4..5, "")
 - (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxyadenosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(6..8, "")
 - (D) OTHER INFORMATION: /note= "The residues at these positions are a 2'deoxythymidine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(9, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyguanosine 5'-O-(1-Thiomonophosphate)."
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(10, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a 2'deoxyctosine 5'-O-(1-Thiomonophosphate)."
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:113:

CCTAATTGTC CAGTTACAAA ATAAACAGCC C

31

(2) INFORMATION FOR SEQ ID NO:114:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 9 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"
- (ix) FEATURE:
 - (A) NAME/KEY: misc_difference
 - (B) LOCATION: replace(1, "")
 - (D) OTHER INFORMATION: /note= "The residue at this position is a spacer bearing a Cy3 dye."

(ix) FEATURE:
 (A) NAME/KEY: modified_base
 (B) LOCATION: 2..3
 (D) OTHER INFORMATION: /mod_base= OTHER
/note= "The residues at these positions have an amino group added."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:114:

NTTCCAGAG

9

(2) INFORMATION FOR SEQ ID NO:115:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 44 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:115:

TTTTCAGAG CCTAATGAAA TTAGGCTCTG GAAAGACGCT CGTG

44

(2) INFORMATION FOR SEQ ID NO:116:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 14 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:116:

AACGAGCGTC TTG

14

(2) INFORMATION FOR SEQ ID NO:117:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 14 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:117:

AACGAGCGTC ATTG

14

(2) INFORMATION FOR SEQ ID NO:118:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 50 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:118:

TTTTTTTTTA ATTAGGCTCT GGAAAGACGC TCGTGAAACG AGCGTCTTTG

50

(2) INFORMATION FOR SEQ ID NO:119:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 17 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:119:

TTTTCAGAG CTAATG

17

(2) INFORMATION FOR SEQ ID NO:120:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 13 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:

- (A) NAME/KEY: misc_difference
- (B) LOCATION: replace(1, "")
- (D) OTHER INFORMATION: /note= "The residue at this position has a TET label."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:120:

CCGGTCGTCC TGG

13

(2) INFORMATION FOR SEQ ID NO:121:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 25 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:121:

CAATTCCGGT GTACTACCG GTTCC

25

(2) INFORMATION FOR SEQ ID NO:122:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 16 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

(ix) FEATURE:
 (A) NAME/KEY: misc_difference
 (B) LOCATION: replace(1, "")
 (D) OTHER INFORMATION: /note= "The residue at this position has a TET label."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:122:

CCGGTCGTCC TGGCAA

16

(2) INFORMATION FOR SEQ ID NO:123:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 47 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:123:

TGTTTTGACC TCCATAGAAG ACCCTATAGT GAGTCGTATT AATTTCG

47

(2) INFORMATION FOR SEQ ID NO:124:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 23 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:124:

CGAAATTAAT ACGACTCACT ATA

23

(2) INFORMATION FOR SEQ ID NO:125:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 30 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:125:

CGAAATTAAT ACGACTCACT ATACCCAGAA

30

(2) INFORMATION FOR SEQ ID NO:126:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 16 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
 (A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:126:
CGAAATTAAT ACGACT 16

(2) INFORMATION FOR SEQ ID NO:127:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 13 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:127:
CGAAATTAAT ACG 13

(2) INFORMATION FOR SEQ ID NO:128:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 12 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:128:
CGAAATTAAT AC 12

(2) INFORMATION FOR SEQ ID NO:129:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 25 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:129:
CACTATAGGG TCTTCTATGG AGGTC 25

(2) INFORMATION FOR SEQ ID NO:130:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 28 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: other nucleic acid
(A) DESCRIPTION: /desc = "DNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:130:
ACTCACTATA GGGTCTTCTA TGGAGGTC 28

(2) INFORMATION FOR SEQ ID NO:131:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 29 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:131:

GACTCACTAT AGGGTCTTCT ATGGAGGTC

29

(2) INFORMATION FOR SEQ ID NO:132:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:132:

CGAAATTAAT ACGCAGTATG TTAGCAAACG

30

(2) INFORMATION FOR SEQ ID NO:133:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 30 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:133:

GAACTGGCAT GATTAAGACT CTTATTACC

30

(2) INFORMATION FOR SEQ ID NO:134:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 29 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
 - (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:134:

GAACTGGCAT GATTAAGACT CTTATTAA

29

(2) INFORMATION FOR SEQ ID NO:135:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 326 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:135:

```

Met Gly Val Gln Phe Gly Asp Phe Ile Pro Lys Asn Ile Ile Ser Phe
 1           5           10           15
Glu Asp Leu Lys Gly Lys Lys Val Ala Ile Asp Gly Met Asn Ala Leu
 20           25           30
Tyr Gln Phe Leu Thr Ser Ile Arg Leu Arg Asp Gly Ser Pro Leu Arg
 35           40           45
Asn Arg Lys Gly Glu Ile Thr Ser Ala Tyr Asn Gly Val Phe Tyr Lys
 50           55           60
Thr Ile His Leu Leu Glu Asn Asp Ile Thr Pro Ile Trp Val Phe Asp
 65           70           75           80
Gly Glu Pro Pro Lys Leu Lys Glu Lys Thr Arg Lys Val Arg Arg Glu
 85           90           95
Met Lys Glu Lys Ala Glu Leu Lys Met Lys Glu Ala Ile Lys Lys Glu
 100          105          110
Asp Phe Glu Glu Ala Ala Lys Tyr Ala Lys Arg Val Ser Tyr Leu Thr
 115          120          125
Pro Lys Met Val Glu Asn Cys Lys Tyr Leu Leu Ser Leu Met Gly Ile
 130          135          140
Pro Tyr Val Glu Ala Pro Ser Glu Gly Glu Ala Gln Ala Ser Tyr Met
 145          150          155          160
Ala Lys Lys Gly Asp Val Trp Ala Val Val Ser Gln Asp Tyr Asp Ala
 165          170          175
Leu Leu Tyr Gly Ala Pro Arg Val Val Arg Asn Leu Thr Thr Thr Lys
 180          185          190
Glu Met Pro Glu Leu Ile Glu Leu Asn Glu Val Leu Glu Asp Leu Arg
 195          200          205
Ile Ser Leu Asp Asp Leu Ile Asp Ile Ala Ile Phe Met Gly Thr Asp
 210          215          220
Tyr Asn Pro Gly Gly Val Lys Gly Ile Gly Phe Lys Arg Ala Tyr Glu
 225          230          235          240
Leu Val Arg Ser Gly Val Ala Lys Asp Val Leu Lys Lys Glu Val Glu
 245          250          255
Tyr Tyr Asp Glu Ile Lys Arg Ile Phe Lys Glu Pro Lys Val Thr Asp
 260          265          270
Asn Tyr Ser Leu Ser Leu Lys Leu Pro Asp Lys Glu Gly Ile Ile Lys
 275          280          285

```

Phe Leu Val Asp Glu Asn Asp Phe Asn Tyr Asp Arg Val Lys Lys His
 290 295 300

Val Asp Lys Leu Tyr Asn Leu Ile Ala Asn Lys Thr Lys Gln Lys Thr
 305 310 315 320

Leu Asp Ala Trp Phe Lys
 325

(2) INFORMATION FOR SEQ ID NO:136:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 340 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:136:

Met Gly Val Pro Ile Gly Glu Ile Ile Pro Arg Lys Glu Ile Glu Leu
 1 5 10 15

Glu Asn Leu Tyr Gly Lys Lys Ile Ala Ile Asp Ala Leu Asn Ala Ile
 20 25 30

Tyr Gln Phe Leu Ser Thr Ile Arg Gln Lys Asp Gly Thr Pro Leu Met
 35 40 45

Asp Ser Lys Gly Arg Ile Thr Ser His Leu Ser Gly Leu Phe Tyr Arg
 50 55 60

Thr Ile Asn Leu Met Glu Ala Gly Ile Lys Pro Val Tyr Val Phe Asp
 65 70 75 80

Gly Glu Pro Pro Glu Phe Lys Lys Lys Glu Leu Glu Lys Arg Arg Glu
 85 90 95

Ala Arg Glu Glu Ala Glu Glu Lys Trp Arg Glu Ala Leu Glu Lys Gly
 100 105 110

Glu Ile Glu Glu Ala Arg Lys Tyr Ala Gln Arg Ala Thr Arg Val Asn
 115 120 125

Glu Met Leu Ile Glu Asp Ala Lys Lys Leu Leu Glu Leu Met Gly Ile
 130 135 140

Pro Ile Val Gln Ala Pro Ser Glu Gly Glu Ala Gln Ala Ala Tyr Met
 145 150 155 160

Ala Ala Lys Gly Ser Val Tyr Ala Ser Ala Ser Gln Asp Tyr Asp Ser
 165 170 175

Leu Leu Phe Gly Ala Pro Arg Leu Val Arg Asn Leu Thr Ile Thr Gly
 180 185 190

Lys Arg Lys Leu Pro Gly Lys Asn Val Tyr Val Glu Ile Lys Pro Glu
 195 200 205

Leu Ile Ile Leu Glu Glu Val Leu Lys Glu Leu Lys Leu Thr Arg Glu
 210 215 220

Lys Leu Ile Glu Leu Ala Ile Leu Val Gly Thr Asp Tyr Asn Pro Gly
 225 230 235 240

Gly Ile Lys Gly Ile Gly Leu Lys Lys Ala Leu Glu Ile Val Arg His
 245 250 255
 Ser Lys Asp Pro Leu Ala Lys Phe Gln Lys Gln Ser Asp Val Asp Leu
 260 265 270
 Tyr Ala Ile Lys Glu Phe Phe Leu Asn Pro Pro Val Thr Asp Asn Tyr
 275 280 285
 Asn Leu Val Trp Arg Asp Pro Asp Glu Glu Gly Ile Leu Lys Phe Leu
 290 295 300
 Cys Asp Glu His Asp Phe Ser Glu Glu Arg Val Lys Asn Gly Leu Glu
 305 310 315 320
 Arg Leu Lys Lys Ala Ile Lys Ser Gly Lys Gln Ser Thr Leu Glu Ser
 325 330 335
 Trp Phe Lys Arg
 340

(2) INFORMATION FOR SEQ ID NO:137:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 380 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:137:

Met Gly Ile Gln Gly Leu Ala Lys Leu Ile Ala Asp Val Ala Pro Ser
 1 5 10 15
 Ala Ile Arg Glu Asn Asp Ile Lys Ser Tyr Phe Gly Arg Lys Val Ala
 20 25 30
 Ile Asp Ala Ser Met Ser Ile Tyr Gln Phe Leu Ile Ala Val Arg Gln
 35 40 45
 Gly Gly Asp Val Leu Gln Asn Glu Glu Gly Glu Thr Thr Ser His Leu
 50 55 60
 Met Gly Met Phe Tyr Arg Thr Ile Arg Met Met Glu Asn Gly Ile Lys
 65 70 75 80
 Pro Val Tyr Val Phe Asp Gly Lys Pro Pro Gln Leu Lys Ser Gly Glu
 85 90 95
 Leu Ala Lys Arg Ser Glu Arg Arg Ala Glu Ala Glu Lys Gln Leu Gln
 100 105 110
 Gln Ala Gln Ala Ala Gly Ala Glu Gln Glu Val Glu Lys Phe Thr Lys
 115 120 125
 Arg Leu Val Lys Val Thr Lys Gln His Asn Asp Glu Cys Lys His Leu
 130 135 140
 Leu Ser Leu Met Gly Ile Pro Tyr Leu Asp Ala Pro Ser Glu Ala Glu
 145 150 155 160
 Ala Ser Cys Ala Ala Leu Val Lys Ala Gly Lys Val Tyr Ala Ala Ala
 165 170 175

```

Thr Glu Asp Met Asp Cys Leu Thr Phe Gly Ser Pro Val Leu Met Arg
      180                      185                      190
His Leu Thr Ala Ser Glu Ala Lys Lys Leu Pro Ile Gln Glu Phe His
      195                      200                      205
Leu Ser Arg Ile Leu Gln Glu Leu Gly Leu Asn Gln Glu Gln Phe Val
      210                      215                      220
Asp Leu Cys Ile Leu Leu Gly Ser Asp Tyr Cys Glu Ser Ile Arg Gly
      225                      230                      235                      240
Ile Gly Pro Lys Arg Ala Val Asp Leu Ile Gln Lys His Lys Ser Ile
      245                      250                      255
Glu Glu Ile Val Arg Arg Leu Asp Pro Asn Lys Tyr Pro Val Pro Glu
      260                      265                      270
Asn Trp Leu His Lys Glu Ala His Gln Leu Phe Leu Glu Pro Glu Val
      275                      280                      285
Leu Asp Pro Glu Ser Val Glu Leu Lys Trp Ser Glu Pro Asn Glu Glu
      290                      295                      300
Glu Leu Ile Lys Phe Met Cys Gly Glu Lys Gln Phe Ser Glu Glu Arg
      305                      310                      315                      320
Ile Arg Ser Gly Val Lys Arg Leu Ser Lys Ser Arg Gln Gly Ser Thr
      325                      330                      335
Gln Gly Arg Leu Asp Asp Phe Phe Lys Val Thr Gly Ser Leu Ser Ser
      340                      345                      350
Ala Lys Arg Lys Glu Pro Glu Pro Lys Gly Ser Thr Lys Lys Lys Ala
      355                      360                      365
Lys Thr Gly Ala Ala Gly Lys Phe Lys Arg Gly Lys
      370                      375                      380

```

(2) INFORMATION FOR SEQ ID NO:138:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 378 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:138:

```

Met Gly Ile His Gly Leu Ala Lys Leu Ile Ala Asp Val Ala Pro Ser
1           5           10           15
Ala Ile Arg Glu Asn Asp Ile Lys Ser Tyr Phe Gly Arg Lys Val Ala
      20           25           30
Ile Asp Ala Ser Met Ser Ile Tyr Gln Phe Leu Ile Ala Val Arg Gln
      35           40           45
Gly Gly Asp Val Leu Gln Asn Glu Glu Gly Glu Thr Thr Ser Leu Met
      50           55           60
Gly Met Phe Tyr Arg Thr Ile Arg Met Glu Asn Gly Ile Lys Pro Val
      65           70           75           80

```



```

Tyr Val Phe Asp Gly Lys Pro Pro Gln Leu Lys Ser Gly Glu Leu Ala
      85                      90                      95
Lys Arg Ser Glu Arg Arg Ala Glu Ala Glu Lys Gln Leu Gln Gln Ala
      100                    105                    110
Gln Glu Ala Gly Met Glu Glu Glu Val Glu Lys Phe Thr Lys Arg Leu
      115                    120                    125
Val Lys Val Thr Lys Gln His Asn Asp Glu Cys Lys His Leu Leu Ser
      130                    135                    140
Leu Met Gly Ile Pro Tyr Leu Asp Ala Pro Ser Glu Ala Glu Ala Ser
      145                    150                    155                    160
Cys Ala Ala Leu Ala Lys Ala Gly Lys Val Tyr Ala Ala Ala Thr Glu
      165                    170                    175
Asp Met Asp Cys Leu Thr Phe Gly Ser Pro Val Leu Met Arg His Leu
      180                    185                    190
Thr Ala Ser Glu Ala Lys Lys Leu Pro Ile Gln Glu Phe His Leu Ser
      195                    200                    205
Arg Val Leu Gln Glu Leu Gly Leu Asn Gln Glu Gln Phe Val Asp Leu
      210                    215                    220
Cys Ile Leu Leu Gly Ser Asp Tyr Cys Glu Ser Ile Arg Gly Ile Gly
      225                    230                    235                    240
Ala Lys Arg Ala Val Asp Leu Ile Gln Lys His Lys Ser Ile Glu Glu
      245                    250                    255
Ile Val Arg Arg Leu Asp Pro Ser Lys Tyr Pro Val Pro Glu Asn Trp
      260                    265                    270
Leu His Lys Glu Ala Gln Gln Leu Phe Leu Glu Pro Glu Val Val Asp
      275                    280                    285
Pro Glu Ser Val Glu Leu Lys Trp Ser Glu Pro Asn Glu Glu Glu Leu
      290                    295                    300
Val Lys Phe Met Cys Gly Glu Lys Gln Phe Ser Glu Glu Arg Ile Arg
      305                    310                    315                    320
Ser Gly Val Lys Arg Leu Ser Lys Ser Arg Gln Gly Ser Thr Gln Gly
      325                    330                    335
Arg Leu Asp Asp Phe Phe Lys Val Thr Gly Ser Leu Ser Ser Ala Lys
      340                    345                    350
Arg Lys Glu Pro Glu Pro Lys Gly Pro Ala Lys Lys Lys Ala Lys Thr
      355                    360                    365
Gly Gly Ala Gly Lys Phe Arg Arg Gly Lys
      370                    375

```

(2) INFORMATION FOR SEQ ID NO:139:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 382 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

- (ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:139:

```

Met Gly Ile Lys Gly Leu Asn Ala Ile Ile Ser Glu His Val Pro Ser
1      5      10      15
Ala Ile Arg Lys Ser Asp Ile Lys Ser Phe Phe Gly Arg Lys Val Ala
20      25      30
Ile Asp Ala Ser Met Ser Leu Tyr Gln Phe Leu Ile Ala Val Arg Gln
35      40      45
Gln Asp Gly Gly Gln Leu Thr Asn Glu Ala Gly Glu Thr Thr Ser His
50      55      60
Leu Met Gly Met Phe Tyr Arg Thr Leu Arg Met Ile Asp Asn Gly Ile
65      70      75      80
Lys Pro Cys Tyr Val Phe Asp Gly Lys Pro Pro Asp Leu Lys Ser His
85      90      95
Glu Leu Thr Lys Arg Ser Ser Arg Arg Val Glu Thr Glu Lys Lys Leu
100     105     110
Ala Glu Ala Thr Thr Glu Leu Glu Lys Met Lys Gln Glu Arg Arg Leu
115     120     125
Val Lys Val Ser Lys Glu His Asn Glu Glu Ala Gln Lys Leu Leu Gly
130     135     140
Leu Met Gly Ile Pro Tyr Ile Ile Ala Pro Thr Glu Ala Glu Ala Gln
145     150     155     160
Cys Ala Glu Leu Ala Lys Lys Gly Lys Val Tyr Ala Ala Ala Ser Glu
165     170     175
Asp Met Asp Thr Leu Cys Tyr Arg Thr Pro Phe Leu Leu Arg His Leu
180     185     190
Thr Phe Ser Glu Ala Lys Lys Glu Pro Ile His Glu Ile Asp Thr Glu
195     200     205
Leu Val Leu Arg Gly Leu Asp Leu Thr Ile Glu Gln Phe Val Asp Leu
210     215     220
Cys Ile Met Leu Gly Cys Asp Tyr Cys Glu Ser Ile Arg Gly Val Gly
225     230     235     240
Pro Val Thr Ala Leu Lys Leu Ile Lys Thr His Gly Ser Ile Glu Lys
245     250     255
Ile Val Glu Phe Ile Glu Ser Gly Glu Ser Asn Asn Thr Lys Trp Lys
260     265     270
Ile Pro Glu Asp Trp Pro Tyr Lys Gln Ala Arg Met Leu Phe Leu Asp
275     280     285
Pro Glu Val Ile Asp Gly Asn Glu Ile Asn Leu Lys Trp Ser Pro Pro
290     295     300
Lys Glu Lys Glu Leu Ile Glu Tyr Leu Cys Asp Asp Lys Lys Phe Ser
305     310     315     320
Glu Glu Arg Val Lys Ser Gly Ile Ser Arg Leu Lys Lys Gly Leu Lys
325     330     335
Ser Gly Ile Gln Gly Arg Leu Asp Gly Phe Phe Gln Val Val Pro Lys
340     345     350

```

Thr Lys Glu Gln Leu Ala Ala Ala Lys Arg Ala Gln Glu Asn Lys
 355 360 365

Lys Leu Asn Lys Asn Lys Asn Lys Val Thr Lys Gly Arg Arg
 370 375 380

(2) INFORMATION FOR SEQ ID NO:140:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 387 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:140:

Met Gly Val His Ser Phe Trp Asp Ile Ala Gly Pro Thr Ala Arg Pro
 1 5 10 15

Val Arg Leu Glu Ser Leu Glu Asp Lys Arg Met Ala Val Asp Ala Ser
 20 25 30

Ile Trp Ile Tyr Gln Phe Leu Lys Ala Val Arg Asp Gln Glu Gly Asn
 35 40 45

Ala Val Lys Asn Ser His Ile Thr Gly Phe Phe Arg Arg Ile Cys Lys
 50 55 60

Leu Leu Tyr Phe Gly Ile Arg Pro Val Phe Val Phe Asp Gly Gly Val
 65 70 75 80

Pro Val Leu Lys Arg Glu Thr Ile Arg Gln Arg Lys Glu Arg Arg Gln
 85 90 95

Gly Lys Arg Glu Ser Ala Lys Ser Thr Ala Arg Lys Leu Leu Ala Leu
 100 105 110

Gln Leu Gln Asn Gly Ser Asn Asp Asn Glu Val Thr Met Asp Met Ile
 115 120 125

Lys Glu Val Gln Glu Leu Leu Ser Arg Phe Gly Ile Pro Tyr Ile Thr
 130 135 140

Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Glu Leu Leu Gln Leu Asn
 145 150 155 160

Leu Val Asp Gly Ile Ile Thr Asp Asp Ser Asp Val Phe Leu Phe Gly
 165 170 175

Gly Thr Lys Ile Tyr Lys Asn Met Phe His Glu Lys Asn Tyr Val Glu
 180 185 190

Phe Tyr Asp Ala Glu Ser Ile Leu Lys Leu Leu Gly Leu Asp Arg Lys
 195 200 205

Asn Met Ile Glu Leu Ala Gln Leu Leu Gly Ser Asp Tyr Thr Asn Gly
 210 215 220

Leu Lys Gly Met Gly Pro Val Ser Ser Ile Glu Val Ile Ala Glu Phe
 225 230 235 240

Gly Asn Leu Lys Asn Phe Lys Asp Trp Tyr Asn Asn Gly Gln Phe Asp
 245 250 255

Lys Arg Lys Gln Glu Thr Glu Asn Lys Phe Glu Lys Asp Leu Arg Lys
 260 265 270
 Lys Leu Val Asn Asn Glu Ile Ile Leu Asp Asp Asp Phe Pro Ser Val
 275 280 285
 Met Val Tyr Asp Ala Tyr Met Arg Pro Glu Val Asp His Asp Thr Thr
 290 295 300
 Pro Phe Val Trp Gly Val Pro Asp Leu Asp Met Leu Arg Ser Phe Met
 305 310 315 320
 Lys Thr Gln Leu Gly Trp Pro His Glu Lys Ser Asp Glu Ile Leu Ile
 325 330 335
 Pro Leu Ile Arg Asp Val Asn Lys Arg Lys Lys Lys Gly Lys Gln Lys
 340 345 350
 Arg Ile Asn Glu Phe Phe Pro Arg Glu Tyr Ile Ser Gly Asp Lys Lys
 355 360 365
 Leu Asn Thr Ser Lys Arg Ile Ser Thr Ala Thr Gly Lys Leu Lys Lys
 370 375 380
 Arg Lys Met
 385

(2) INFORMATION FOR SEQ ID NO:141:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 488 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:141:

Met Gly Val Ser Gly Leu Trp Asn Ile Leu Glu Pro Val Lys Arg Pro
 1 5 10 15
 Val Lys Leu Glu Thr Leu Val Asn Lys Arg Leu Ala Ile Asp Ala Ser
 20 25 30
 Ile Trp Ile Tyr Gln Phe Leu Lys Ala Val Arg Asp Lys Glu Gly Asn
 35 40 45
 Gln Leu Lys Ser Ser His Val Val Gly Phe Phe Arg Arg Ile Cys Lys
 50 55 60
 Leu Leu Phe Phe Gly Ile Lys Pro Val Phe Val Phe Asp Gly Gly Ala
 65 70 75 80
 Pro Ser Leu Lys Arg Gln Thr Ile Gln Lys Arg Gln Ala Arg Arg Leu
 85 90 95
 Asp Arg Glu Glu Asn Ala Thr Val Thr Ala Asn Lys Leu Leu Ala Leu
 100 105 110
 Gln Met Arg His Gln Ala Met Leu Leu Lys Arg Asp Ala Asp Glu Val
 115 120 125
 Thr Gln Val Met Ile Lys Glu Cys Gln Glu Leu Leu Arg Leu Phe Gly
 130 135 140

Leu Pro Tyr Ile Val Ala Pro Gln Glu Ala Glu Ala Gln Cys Ser Lys
 145 150 155 160
 Leu Leu Glu Leu Lys Leu Val Asp Gly Ile Val Thr Asp Asp Ser Asp
 165 170 175
 Val Phe Leu Phe Gly Gly Thr Arg Val Tyr Arg Asn Met Phe Asn Gln
 180 185 190
 Asn Lys Phe Val Glu Leu Tyr Leu Met Asp Asp Met Lys Arg Glu Phe
 195 200 205
 Asn Val Asn Gln Met Asp Leu Ile Lys Leu Ala His Leu Leu Gly Ser
 210 215 220
 Asp Tyr Thr Met Gly Leu Ser Arg Val Gly Pro Val Leu Ala Leu Glu
 225 230 235 240
 Ile Leu His Glu Phe Pro Gly Asp Thr Gly Leu Phe Glu Phe Lys Lys
 245 250 255
 Trp Phe Gln Arg Leu Ser Thr Gly His Ala Ser Lys Asn Asp Val Asn
 260 265 270
 Thr Pro Val Lys Lys Arg Ile Asn Lys Leu Val Gly Lys Ile Ile Leu
 275 280 285
 Pro Ser Glu Phe Pro Asn Pro Leu Val Asp Glu Ala Tyr Leu His Pro
 290 295 300
 Ala Val Asp Asp Ser Lys Gln Ser Phe Gln Trp Gly Ile Pro Asp Leu
 305 310 315 320
 Asp Glu Leu Arg Gln Phe Leu Met Ala Thr Val Gly Trp Ser Lys Gln
 325 330 335
 Arg Thr Asn Glu Val Leu Leu Pro Val Ile Gln Asp Met His Lys Lys
 340 345 350
 Gln Phe Val Gly Thr Gln Ser Asn Leu Thr Gln Phe Phe Glu Gly Gly
 355 360 365
 Asn Thr Asn Val Tyr Ala Pro Arg Val Ala Tyr His Phe Lys Ser Lys
 370 375 380
 Arg Leu Glu Asn Ala Leu Ser Ser Phe Lys Asn Gln Ile Ser Asn Gln
 385 390 395 400
 Ser Pro Met Ser Glu Glu Ile Gln Ala Asp Ala Asp Ala Phe Gly Glu
 405 410 415
 Ser Lys Gly Ser Asp Glu Leu Gln Ser Arg Ile Leu Arg Arg Lys Lys
 420 425 430
 Met Met Ala Ser Lys Asn Ser Ser Asp Ser Asp Ser Asp Ser Glu Asp
 435 440 445
 Asn Phe Leu Ala Ser Leu Thr Pro Lys Thr Asn Ser Ser Ser Ile Ser
 450 455 460
 Ile Glu Asn Leu Pro Arg Lys Thr Lys Leu Ser Thr Ser Leu Leu Lys
 465 470 475 480
 Lys Pro Ser Lys Arg Arg Arg Lys
 485

(2) INFORMATION FOR SEQ ID NO:142:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 550 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS: not relevant
 (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:142:

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Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly Arg Gln
 1           5           10           15
Val Ser Pro Glu Ala Leu Glu Gly Lys Ile Leu Ala Val Asp Ile Ser
          20           25           30
Ile Trp Leu Asn Gln Ala Leu Lys Gly Val Arg Asp Arg His Gly Asn
          35           40           45
Ser Ile Glu Asn Pro His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
          50           55           60
Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Asp Ala
          65           70           75           80
Pro Leu Leu Lys Lys Gln Thr Leu Val Lys Arg Arg Gln Arg Lys Asp
          85           90           95
Leu Ala Ser Ser Asp Ser Arg Lys Thr Thr Glu Lys Leu Leu Lys Thr
          100          105          110
Phe Leu Lys Arg Gln Ala Ile Lys Thr Glu Arg Ile Ala Ala Thr Val
          115          120          125
Thr Gly Gln Met Phe Leu Glu Ser Gln Glu Leu Leu Arg Leu Phe Gly
          130          135          140
Ile Pro Tyr Ile Gln Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Ile
          145          150          155          160
Leu Asp Leu Thr Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
          165          170          175
Ile Trp Leu Phe Gly Ala Arg His Val Tyr Arg Asn Phe Phe Asn Lys
          180          185          190
Asn Lys Phe Val Glu Tyr Tyr Gln Tyr Val Asp Phe His Asn Gln Leu
          195          200          205
Gly Leu Asp Arg Asn Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
          210          215          220
Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Cys Val Thr Ala Met Glu
          225          230          235          240
Ile Leu Asn Glu Phe Pro Gly His Gly Leu Glu Pro Leu Leu Lys Phe
          245          250          255
Ser Glu Trp Trp His Glu Ala Gln Lys Asn Pro Lys Ile Arg Pro Asn
          260          265          270
Pro His Asp Thr Lys Val Lys Lys Lys Leu Arg Thr Leu Gln Leu Thr
          275          280          285

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Pro Gly Phe Pro Asn Pro Ala Val Ala Glu Ala Tyr Leu Lys Pro Val
 290          295          300
Val Asp Asp Ser Lys Gly Ser Phe Leu Trp Gly Lys Pro Asp Leu Asp
 305          310          315          320
Lys Ile Arg Glu Phe Cys Gln Arg Tyr Phe Gly Trp Asn Arg Thr Lys
          325          330          335
Thr Asp Glu Ser Leu Phe Pro Val Leu Lys Gln Leu Asp Ala Gln Gln
          340          345          350
Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Ala Gln Gln Glu Lys
          355          360          365
Glu Asp Ala Lys Arg Ile Lys Ser Gln Arg Leu Asn Arg Ala Val Thr
          370          375          380
Cys Met Leu Arg Lys Glu Lys Glu Ala Ala Ala Ser Glu Ile Glu Ala
 385          390          395          400
Val Ser Val Ala Met Glu Lys Glu Phe Glu Leu Leu Asp Lys Ala Lys
          405          410          415
Arg Lys Thr Gln Lys Arg Gly Ile Thr Asn Thr Leu Glu Glu Ser Ser
          420          425          430
Ser Leu Lys Arg Lys Arg Leu Ser Asp Ser Lys Arg Lys Asn Thr Cys
          435          440          445
Gly Gly Phe Leu Gly Glu Thr Cys Leu Ser Glu Ser Ser Asp Gly Ser
          450          455          460
Ser Ser Glu His Ala Glu Ser Ser Ser Leu Met Asn Val Gln Arg Arg
 465          470          475          480
Thr Ala Ala Lys Glu Pro Lys Thr Ser Ala Ser Asp Ser Gln Asn Ser
          485          490          495
Val Lys Glu Ala Pro Val Lys Asn Gly Gly Ala Thr Thr Ser Ser Ser
          500          505          510
Ser Asp Ser Asp Asp Asp Gly Gly Lys Glu Lys Met Val Leu Val Thr
          515          520          525
Ala Arg Ser Val Phe Gly Lys Lys Arg Arg Lys Leu Arg Arg Ala Arg
          530          535          540
Gly Arg Lys Arg Lys Thr
 545          550

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(2) INFORMATION FOR SEQ ID NO:143:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 543 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS: not relevant
- (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:143:

Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly His Arg
 1 5 10 15
 Val Ser Pro Glu Ala Leu Glu Gly Lys Val Leu Ala Val Asp Ile Ser
 20 25 30
 Ile Trp Leu Asn Gln Ala Leu Lys Gly Val Arg Asp Ser His Gly Asn
 35 40 45
 Val Ile Glu Asn Ala His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
 50 55 60
 Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Asp Ala
 65 70 75 80
 Pro Leu Leu Lys Lys Gln Thr Leu Ala Lys Arg Arg Gln Arg Lys Asp
 85 90 95
 Ser Ala Ser Ile Asp Ser Arg Lys Thr Thr Glu Lys Leu Leu Lys Thr
 100 105 110
 Phe Leu Lys Arg Gln Ala Leu Lys Thr Asp Arg Ile Ala Ala Ser Val
 115 120 125
 Thr Gly Gln Met Phe Leu Glu Ser Gln Glu Leu Leu Arg Leu Phe Gly
 130 135 140
 Val Pro Tyr Ile Gln Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Val
 145 150 155 160
 Leu Asp Leu Ser Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
 165 170 175
 Ile Trp Leu Phe Gly Ala Arg His Val Tyr Lys Asn Phe Phe Asn Lys
 180 185 190
 Asn Lys Phe Val Glu Tyr Tyr Gln Tyr Val Asp Phe Tyr Ser Gln Leu
 195 200 205
 Gly Leu Asp Arg Asn Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
 210 215 220
 Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Cys Val Thr Ala Met Glu
 225 230 235 240
 Ile Leu Asn Glu Phe Pro Gly Arg Gly Leu Asp Pro Leu Leu Lys Phe
 245 250 255
 Ser Glu Trp Trp His Glu Ala Gln Asn Asn Lys Lys Val Ala Glu Asn
 260 265 270
 Pro Tyr Asp Thr Lys Val Lys Lys Lys Leu Arg Lys Leu Gln Leu Thr
 275 280 285
 Pro Gly Phe Pro Asn Pro Ala Val Ala Asp Ala Tyr Leu Arg Pro Val
 290 295 300
 Val Asp Asp Ser Arg Gly Ser Phe Leu Trp Gly Lys Pro Asp Val Asp
 305 310 315 320
 Lys Ile Arg Glu Phe Cys Gln Arg Tyr Phe Gly Trp Asn Arg Met Lys
 325 330 335
 Thr Asp Glu Ser Leu Tyr Pro Val Leu Lys His Leu Asn Ala His Gln
 340 345 350


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Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Ala Gln Gln Glu Lys
   355                               360                               365
Gln Asp Ala Lys Leu Ile Lys Ser His Arg Leu Ser Arg Ala Val Thr
   370                               375                               380
Cys Met Leu Arg Lys Glu Arg Glu Glu Lys Ala Pro Glu Leu Thr Lys
   385                               390                               395                               400
Val Thr Glu Ala Met Glu Lys Glu Phe Glu Leu Leu Asp Asp Ala Lys
                               405                               410                               415
Gly Lys Thr Gln Lys Arg Glu Leu Pro Tyr Lys Lys Glu Thr Ser Val
                               420                               425                               430
Pro Lys Arg Arg Arg Pro Ser Gly Asn Gly Gly Phe Leu Gly Asp Pro
                               435                               440                               445
Tyr Cys Ser Glu Ser Pro Gln Glu Ser Ser Cys Glu Asp Gly Glu Gly
   450                               455                               460
Ser Ser Val Met Ser Ala Arg Gln Arg Ser Ala Ala Glu Ser Ser Lys
   465                               470                               475                               480
Ile Gly Cys Ser Asp Val Pro Asp Leu Val Arg Asp Ser Pro His Gly
                               485                               490                               495
Arg Gln Gly Cys Val Ser Thr Ser Ser Ser Asp Ser Glu Asp Gly Glu
                               500                               505                               510
Asp Lys Ala Lys Thr Val Leu Val Thr Ala Arg Pro Val Phe Gly Lys
   515                               520                               525
Lys Arg Arg Lys Leu Lys Ser Met Lys Arg Arg Lys Lys Lys Thr
   530                               535                               540

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(2) INFORMATION FOR SEQ ID NO:144:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 527 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:144:

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Met Gly Val Gln Gly Leu Trp Lys Leu Leu Glu Cys Ser Gly Arg Pro
 1                               5                               10                               15
Ile Asn Pro Gly Thr Leu Glu Gly Lys Ile Leu Ala Val Asp Ile Ser
                20                               25                               30
Ile Trp Leu Asn Gln Ala Val Lys Gly Ala Arg Asp Arg Gln Gly Asn
   35                               40                               45
Ala Ile Gln Asn Ala His Leu Leu Thr Leu Phe His Arg Leu Cys Lys
   50                               55                               60
Leu Leu Phe Phe Arg Ile Arg Pro Ile Phe Val Phe Asp Gly Glu Ala
   65                               70                               75                               80
Pro Leu Leu Lys Arg Gln Thr Leu Ala Lys Arg Arg Gln Arg Thr Asp
                85                               90                               95

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Lys Ala Ser Asn Asp Ala Arg Lys Thr Asn Glu Lys Leu Leu Arg Thr
 100 105 110
 Phe Leu Lys Arg Gln Ala Ile Lys Ala Glu Arg Ile Ala Ala Thr Val
 115 120 125
 Thr Gly Gln Met Cys Leu Glu Ser Gln Glu Leu Leu Gln Leu Phe Gly
 130 135 140
 Ile Pro Tyr Ile Val Ala Pro Met Glu Ala Glu Ala Gln Cys Ala Ile
 145 150 155 160
 Leu Asp Leu Thr Asp Gln Thr Ser Gly Thr Ile Thr Asp Asp Ser Asp
 165 170 175
 Ile Trp Leu Phe Gly Ala Arg His Val Tyr Lys Asn Phe Phe Ser Gln
 180 185 190
 Asn Lys His Val Glu Tyr Tyr Gln Tyr Ala Asp Ile His Asn Gln Leu
 195 200 205
 Gly Leu Asp Arg Ser Lys Leu Ile Asn Leu Ala Tyr Leu Leu Gly Ser
 210 215 220
 Asp Tyr Thr Glu Gly Ile Pro Thr Val Gly Tyr Val Ser Ala Met Glu
 225 230 235 240
 Ile Leu Asn Glu Phe Pro Gly Gln Gly Leu Glu Pro Leu Val Lys Phe
 245 250 255
 Lys Glu Trp Trp Ser Glu Ala Gln Lys Asp Lys Lys Met Arg Pro Asn
 260 265 270
 Pro Asn Asp Thr Lys Val Lys Lys Lys Leu Arg Leu Leu Asp Leu Gln
 275 280 285
 Gln Ser Phe Pro Asn Pro Ala Val Ala Ser Ala Tyr Leu Lys Pro Val
 290 295 300
 Val Asp Glu Ser Lys Ser Ala Phe Ser Trp Gly Arg Pro Asp Leu Glu
 305 310 315 320
 Gln Ile Arg Glu Phe Cys Glu Ser Arg Phe Gly Trp Tyr Arg Leu Lys
 325 330 335
 Thr Asp Glu Val Leu Leu Pro Val Leu Lys Gln Leu Asn Ala Gln Gln
 340 345 350
 Thr Gln Leu Arg Ile Asp Ser Phe Phe Arg Leu Glu Gln His Glu Ala
 355 360 365
 Ala Gly Leu Lys Ser Gln Arg Leu Arg Arg Ala Val Thr Cys Met Lys
 370 375 380
 Arg Lys Glu Arg Asp Val Glu Ala Glu Glu Val Glu Ala Ala Val Ala
 385 390 395 400
 Val Met Glu Arg Glu Cys Thr Asn Gln Arg Lys Gly Gln Lys Thr Asn
 405 410 415
 Thr Lys Ser Gln Gly Thr Lys Arg Arg Lys Pro Thr Glu Cys Ser Gln
 420 425 430
 Glu Asp Gln Asp Pro Gly Gly Gly Phe Ile Gly Ile Glu Leu Lys Thr
 435 440 445

Leu Ser Ser Lys Ala Tyr Ser Ser Asp Gly Ser Ser Ser Asp Ala Glu
 450 455 460
 Asp Leu Pro Ser Gly Leu Ile Asp Lys Gln Ser Gln Ser Gly Ile Val
 465 470 475 480
 Gly Arg Gln Lys Ala Ser Asn Lys Val Glu Ser Ser Ser Ser Ser Asp
 485 490 495
 Asp Glu Asp Arg Thr Val Met Val Thr Ala Lys Pro Val Phe Gln Gly
 500 505 510
 Lys Lys Thr Lys Ser Lys Thr Met Lys Glu Thr Val Lys Arg Lys
 515 520 525

(2) INFORMATION FOR SEQ ID NO:145:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 434 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS: not relevant
 - (D) TOPOLOGY: not relevant

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:145:

Met Thr Ile Asn Gly Ile Trp Glu Trp Ala Asn His Val Val Arg Lys
 1 5 10 15
 Val Pro Asn Glu Thr Met Arg Asp Lys Thr Leu Ser Ile Asp Gly His
 20 25 30
 Ile Trp Leu Tyr Glu Ser Leu Lys Gly Cys Glu Ala His His Gln Gln
 35 40 45
 Thr Pro Asn Ser Tyr Leu Val Thr Phe Phe Thr Arg Ile Gln Arg Leu
 50 55 60
 Leu Glu Leu Lys Ile Ile Pro Ile Val Val Phe Asp Asn Ile Asn Ala
 65 70 75 80
 Ser Ser Ser Ala His Glu Ser Lys Asp Gln Asn Glu Phe Val Pro Arg
 85 90 95
 Lys Arg Arg Ser Phe Gly Asp Ser Pro Phe Thr Asn Leu Val Asp His
 100 105 110
 Val Tyr Lys Thr Asn Ala Leu Leu Thr Glu Leu Gly Ile Lys Val Ile
 115 120 125
 Ile Ala Pro Gly Asp Gly Glu Ala Gln Cys Ala Arg Leu Glu Asp Leu
 130 135 140
 Gly Val Thr Ser Gly Cys Ile Thr Thr Asp Phe Asp Tyr Phe Leu Phe
 145 150 155 160
 Gly Gly Lys Asn Leu Tyr Arg Phe Asp Phe Thr Ala Gly Thr Ser Ser
 165 170 175
 Thr Ala Cys Leu His Asp Ile Met His Leu Ser Leu Gly Arg Met Phe
 180 185 190
 Met Glu Lys Lys Val Ser Arg Pro His Leu Ile Ser Thr Ala Ile Leu
 195 200 205

Leu Gly Cys Asp Tyr Phe Gln Arg Gly Val Gln Asn Ile Gly Ile Val
 210 215 220
 Ser Val Phe Asp Ile Leu Gly Glu Phe Gly Asp Asp Gly Asn Glu Glu
 225 230 235 240
 Ile Asp Pro His Val Ile Leu Asp Arg Phe Ala Ser Tyr Val Arg Glu
 245 250 255
 Glu Ile Pro Ala Arg Ser Glu Asp Thr Gln Arg Lys Leu Arg Leu Arg
 260 265 270
 Arg Lys Lys Tyr Asn Phe Pro Val Gly Phe Pro Asn Cys Asp Ala Val
 275 280 285
 His Asn Ala Ile Thr Met Tyr Leu Arg Pro Pro Val Ser Ser Glu Ile
 290 295 300
 Pro Lys Ile Ile Pro Arg Ala Ala Asn Phe Gln Gln Val Ala Glu Ile
 305 310 315 320
 Met Met Lys Glu Cys Gly Trp Pro Ala Thr Arg Thr Gln Lys Glu Leu
 325 330 335
 Ala Leu Ser Ile Arg Arg Lys Val His Leu Thr Thr Thr Val Ala Gln
 340 345 350
 Thr Arg Ile Pro Asp Phe Phe Ala Ala Thr Lys Ser Lys Asn Phe Thr
 355 360 365
 Pro Ile Val Glu Pro Cys Glu Ser Leu Glu Asp Tyr Ile Ser Ala Asn
 370 375 380
 Asn Thr Trp Met Arg Lys Arg Lys Arg Ser Glu Ser Pro Gln Ile Leu
 385 390 395 400
 Gln His His Ala Lys Arg Gln Val Pro Asp Arg Lys Arg Ser Val Lys
 405 410 415
 Ile Arg Ala Phe Lys Pro Tyr Pro Thr Asp Val Ile Glu Leu Gly Asp
 420 425 430
 Ser Asp

(2) INFORMATION FOR SEQ ID NO:146:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 33 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: other nucleic acid
- (A) DESCRIPTION: /desc = "DNA"

- (xi) SEQUENCE DESCRIPTION: SEQ ID NO:146:

TACTGACTCA CTATAGGGTC TTCTATGGAG GTC

CLAIMS

We claim:

- 5 1. A thermostable structure-specific nuclease having an amino acid sequence
selected from the group consisting of SEQ ID NOS:61, 66, 69 and 71.
2. The nuclease of Claim 1, wherein said nuclease is encoded by a DNA sequence
selected from the group consisting of SEQ ID NO:60, 65, 68 and 70.
- 10 3. A recombinant DNA vector comprising DNA having a nucleotide sequence
encoding a structure-specific nuclease, said nucleotide sequence selected from the group
consisting of SEQ ID NO:60, 65, 68 and 70.
- 15 4. A host cell transformed with the recombinant vector of Claim 3.
5. The host cell of Claim 4, wherein said host cell is an *Escherichia coli* cell.
6. A purified *Pyrococcus woesei* FEN-1 endonuclease.
- 20 7. The purified endonuclease of Claim 6, wherein said endonuclease has a
molecular weight of about 38.7 kilodaltons.
8. An isolated oligonucleotide encoding a *Pyrococcus woesei* FEN-1
25 endonuclease, said oligonucleotide having a region capable of hybridizing an oligonucleotide
sequence selected from the group consisting of SEQ ID NOS:80-83.
9. The isolated oligonucleotide of Claim 8, wherein said oligonucleotide encoding
said endonuclease is operably linked to a heterologous promoter.

30

10. A recombinant DNA vector comprising an isolated oligonucleotide encoding a *Pyrococcus woesei* FEN-1 endonuclease, said oligonucleotide having a region capable of hybridizing an oligonucleotide sequence selected from the group consisting of SEQ ID NOS:80-83.

5

11. A host cell transformed with the recombinant vector of Claim 10.

12. The host cell of Claim 11, wherein said host cell is an *Escherichia coli* cell.

10

13. An isolated oligonucleotide comprising a gene encoding a *Pyrococcus woesei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons.

14. The isolated oligonucleotide of Claim 13, wherein said gene encoding a *Pyrococcus woesei* FEN-1 endonuclease is operably linked to a heterologous promoter.

15

15. A recombinant DNA vector comprising DNA having a nucleotide sequence encoding a *Pyrococcus woesei* FEN-1 endonuclease having a molecular weight of about 38.7 kilodaltons.

20

16. A host cell transformed with the recombinant vector of Claim 15.

17. A composition comprising a cleavage structure, said cleavage structure comprising:

25

a) a target nucleic acid, said target nucleic acid having a first region, a second region, a third region and a fourth region, wherein said first region is located adjacent to and downstream from said second region, said second region is located adjacent to and downstream from said third region and said third region is located adjacent to and downstream from said fourth region;

30

b) a first oligonucleotide complementary to said fourth region of said target nucleic acid;

c) a second oligonucleotide having a 5' portion and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid and wherein said 3' portion of said

second oligonucleotide contains a sequence complementary to said third region of said target nucleic acid; and

- 5 d) a third oligonucleotide having a 5' portion and a 3' portion wherein said 5' portion of said third oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said third oligonucleotide contains a sequence complementary to said second region of said target nucleic acid.

10 18. The cleavage structure of Claim 17, wherein said first region of said target nucleic acid has a length of eleven to fifty nucleotides.

 19. The cleavage structure of Claim 17, wherein said second region of said target nucleic acid has a length of one to three nucleotides.

15 20. The cleavage structure of Claim 17, wherein said third region of said target nucleic acid has a length of six to nine nucleotides.

 21. The cleavage structure of Claim 17, wherein said forth region of said target nucleic acid has a length of six to fifty nucleotides.

20

 22. The cleavage structure of Claim 17, wherein one or more of said first, said second, said third and said fourth oligonucleotides contain a dideoxynucleotide on at the 3' terminus.

25 23. The cleavage structure of Claim 17, wherein said target nucleic acid is not completely complementary to at least one of said first, said second, said third and said fourth oligonucleotides.

 24. The cleavage structure of Claim 23, wherein said target nucleic acid is not
30 completely complementary to said second oligonucleotide.

25. A method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising:

a) providing:

i) a cleavage means,

5 ii) a source of target nucleic acid, said target nucleic acid having a first region, a second region and a third region, wherein said first region is located adjacent to and downstream from said second region and wherein said second region is located adjacent to and downstream from said third region;

10 iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide is completely complementary to said second region of said target nucleic acid and wherein said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said target nucleic acid;

15 iv) a second oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid;

20 b) mixing said cleavage means, said target nucleic acid, said first oligonucleotide and said second oligonucleotide to create a reaction mixture under reaction conditions such that at least said 3' portion of said first oligonucleotide is annealed to said target nucleic acid and wherein at least said 5' portion of said second oligonucleotide is annealed to said target nucleic acid so as to create a cleavage structure and wherein cleavage of said cleavage structure occurs to generate non-target
25 cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and

c) detecting said non-target cleavage products.

26. A method for detecting the presence of a target nucleic acid in a sample by generating non-target cleavage products, comprising:

30 a) providing:

i) a cleavage means;

ii) a sample suspected of containing a target nucleic acid having a first region, a second region and a third region, wherein said first region is

located adjacent to and downstream from said second region and wherein said second region is located adjacent to and downstream from said third region;

iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide is completely complementary to said second region of said target nucleic acid and wherein said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said target nucleic acid;

iv) a second oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid;

b) mixing said cleavage means and said first and said second oligonucleotides to create a reaction mixture under reaction conditions wherein said target nucleic acid and said first and second oligonucleotides form one or more cleavage structures and wherein said cleavage means cleaves said cleavage structures resulting in the cleavage of said first oligonucleotide; and

c) distinguishing said cleaved first oligonucleotide from said uncleaved first oligonucleotide, said second oligonucleotide and said target nucleic acid.

27. The method of Claim 26, wherein said distinguishing comprises electrophoresis of said reaction mixture after said cleavage has occurred to separate said cleaved first oligonucleotide from said uncleaved first oligonucleotide, said second oligonucleotide and said target nucleic acid followed by visualization of said separated cleaved first oligonucleotide.

28. The method of Claim 27, wherein said first oligonucleotide contains a fluorescent label and said visualization consists of detecting said label using a fluorescence imager.

29. The method of Claim 26, wherein said first oligonucleotide is present in excess relative to said target nucleic acid.

30. The method of Claim 26, further comprising measuring the amount of cleaved first oligonucleotide such that the amount of said target nucleic acid present in said sample can be determined.

5 31. A method of detecting sequence variation in a plurality of nucleic acid target sequences wherein said target nucleic acid sequences differ in sequence. comprising:

a) providing:

i) a cleavage means;

10 ii) a sample suspected of containing a first target nucleic acid and a second target nucleic acid, wherein said first and said second target nucleic acid have a first region, a second region and a third region, wherein said first region is located adjacent to and downstream from said second region and wherein said second region is located adjacent to and downstream from said third region and wherein the sequence of said first and second target nucleic acids differ
15 from one another by at least one nucleotide within their respective third regions;

iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide is completely complementary to said second region of said first and said second target nucleic acids and wherein
20 said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said first target nucleic acid;

iv) a second oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said second region of said first and said second target nucleic acids and wherein said 3' portion of said second oligonucleotide contains a
25 sequence complementary to said third region of said second target nucleic acid;

v) a third oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said third oligonucleotide contains a sequence complementary to said first region of said first and said second target nucleic acids and wherein
30 said 3' portion of said third oligonucleotide contains a sequence complementary to said first and said second region of said target nucleic acids;

b) mixing said cleavage means, said first and said second target nucleic acids, said first oligonucleotide, said second oligonucleotide and said third

oligonucleotide to create a reaction mixture under reaction conditions such that said first and second target nucleic acids and said first, said second and said third oligonucleotides form one or more cleavage structures and said cleavage means cleaves said cleavage structures resulting in the cleavage of one or more of said first and said second oligonucleotides;

c) distinguishing said cleaved first and said second oligonucleotides from said uncleaved first and second oligonucleotides, said third oligonucleotide and said first and said second target nucleic acids.

32. The method of Claim 31, wherein said first oligonucleotide contains a first label and said second oligonucleotide contains a second label.

33. The method of Claim 32, wherein said distinguishing comprises separation of said cleaved first oligonucleotide from said uncleaved first oligonucleotide, said second oligonucleotide and said target nucleic acid and further comprising the step d) of detecting said separated cleaved and uncleaved products to permit a determination of the presence and relative abundance of said first and said second target nucleic acids in said sample.

34. The method of Claim 31, wherein said conditions of step b) comprise the use of a cleavage reaction temperature which is less than the melting temperature of said first and said second oligonucleotides and greater than the melting temperature of said 3' portion of said first oligonucleotide and said 3' portion of said second oligonucleotide.

35. A method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising:

a) providing:

i) a cleavage means,

ii) a source of target nucleic acid, said target nucleic acid having a first region, a second region and a third region, wherein said first region is located adjacent to and downstream from said second region and wherein said second region is located adjacent to and downstream from said third region;

iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide contains a sequence complementary to

said second region of said target nucleic acid and wherein said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said target nucleic acid;

iv) a second oligonucleotide having a length between eleven to fifteen nucleotides and further having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid;

b) mixing said cleavage means, said target nucleic acid, said first oligonucleotide and said second oligonucleotide to create a reaction mixture under reaction conditions such that at least said 3' portion of said first oligonucleotide is annealed to said target nucleic acid and wherein at least said 5' portion of said second oligonucleotide is annealed to said target nucleic acid so as to create a cleavage structure and wherein cleavage of said cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and

c) detecting said non-target cleavage products.

36. The method of Claim 35, wherein said cleavage means is a structure-specific nuclease.

37. The method of Claim 35, wherein said second region of said target nucleic acid has a length between one to 5 nucleotides.

38. The method of Claim 35, wherein one or more of said first and said second oligonucleotides contain a dideoxynucleotide at the 3' terminus.

39. The method of Claim 35, wherein said detecting said non-target cleavage products comprises:

a) incubating said non-target cleavage products with a template-independent polymerase and at least one labelled nucleoside triphosphate under conditions such that at least one labelled nucleotide is added to the 3'-hydroxyl group

of said non-target cleavage products to generate labelled non-target cleavage products;
and

- b) detecting the presence of said labelled non-target cleavage products.

5 40. The method of Claim 35, wherein said detecting said non-target cleavage products comprises:

- a) incubating said non-target cleavage products with a template-independent polymerase and at least one nucleoside triphosphate under conditions such that at least one nucleotide is added to the 3'-hydroxyl group of said non-target
10 cleavage products to generate tailed non-target cleavage products; and
b) detecting the presence of said tailed non-target cleavage products.

41. A method of detecting the presence of a target RNA molecule by detecting non-target cleavage products comprising:

- 15 a) providing:
 i) a cleavage means,
 ii) a source of target RNA, said target RNA having a first region, a second region and a third region, wherein said first region is located adjacent to and downstream from said second region and wherein said second region is
20 located adjacent to and downstream from said third region;
 iii) a first oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said first oligonucleotide contains a sequence complementary to said second region of said target RNA and wherein said 3' portion of said first oligonucleotide contains a sequence complementary to said third region of said
25 target RNA;
 iv) a second oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said first region of said target RNA and wherein said 3' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid;
30 b) mixing said cleavage means, said target RNA, said first oligonucleotide and said second oligonucleotide to create a reaction mixture under reaction conditions such that at least said 3' portion of said first oligonucleotide is annealed to said target

RNA and wherein at least said 5' portion of said second oligonucleotide is annealed to said target RNA so as to create a cleavage structure and wherein cleavage of said cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and

5 c) detecting said non-target cleavage products.

42. A method of detecting the presence of a target nucleic acid molecule by detecting non-target cleavage products comprising:

a) providing:

10 i) a cleavage means,
ii) a source of target nucleic acid, said target nucleic acid having a first region, a second region, a third region and a fourth region, wherein said first region is located adjacent to and downstream from said second region, said second region is located adjacent to and downstream from said third region and
15 said third region is located adjacent to and downstream from said fourth region;

iii) a first oligonucleotide complementary to said fourth region of said target nucleic acid;

iv) a second oligonucleotide having a 5' portion and a 3' portion wherein said 5' portion of said second oligonucleotide contains a sequence complementary to said second region of said target nucleic acid and wherein
20 said 3' portion of said second oligonucleotide contains a sequence complementary to said third region of said target nucleic acid;

iv) a third oligonucleotide having a 5' and a 3' portion wherein said 5' portion of said third oligonucleotide contains a sequence complementary to said first region of said target nucleic acid and wherein said 3' portion of said
25 third oligonucleotide contains a sequence complementary to said second region of said target nucleic acid;

b) mixing said cleavage means, said target nucleic acid, said first oligonucleotide, said second oligonucleotide and said third oligonucleotide to create a
30 reaction mixture under reaction conditions such that said first oligonucleotide is annealed to said fourth region of said target nucleic acid and wherein at least said 3' portion of said second oligonucleotide is annealed to said target nucleic acid and wherein at least said 5' portion of said third oligonucleotide is annealed to said target

nucleic acid so as to create a cleavage structure and wherein cleavage of said cleavage structure occurs to generate non-target cleavage products, each non-target cleavage product having a 3'-hydroxyl group; and

c) detecting said non-target cleavage products.

5

43. The method of Claim 42, wherein said cleavage means is a structure-specific nuclease.

44. The method of Claim 42, wherein one or more of said first, second, and said
10 third oligonucleotides contain a dideoxynucleotide at the 3' terminus.

45. A method of detecting cleaved nucleic molecules, comprising:

a) providing:

i) a homogeneous plurality of charge-balanced oligonucleotides;
15 ii) a sample suspected of containing a target nucleic acid having a sequence comprising a first region complementary to said charge-balanced oligonucleotide;

iii) a cleavage means; and

iv) a reaction vessel;

20 b) adding to said vessel, in any order, said sample, said charge-balanced oligonucleotides and said cleavage means to create a reaction mixture under conditions such that a portion of said charge-balanced oligonucleotides binds to said complementary target nucleic acid to create a bound population, and such that said cleavage means cleaves at least a portion of said bound population of charge-balanced
25 oligonucleotides to produce a population of unbound, charge-unbalanced oligonucleotides; and

c) separating said unbound, charge-unbalanced oligonucleotides from said reaction mixture.

30

46. The method of Claim 45 further comprising providing a homogeneous plurality of oligonucleotides complementary to a second region of said target nucleic acid, wherein said oligonucleotides are capable of binding to said target nucleic acid upstream of said charge-balanced oligonucleotides.

47. The method of Claim 46, wherein said first and said second region of said target nucleic acid share a region of overlap.

48. The method of Claim 42, wherein said cleavage means comprises a thermostable structure-specific nuclease.

49. The method of Claim 45, wherein said target nucleic acid comprises single-stranded DNA.

50. The method of Claim 45, wherein said target nucleic acid comprises double-stranded DNA and prior to the addition of said cleavage means said reaction mixture is treated such that said double-stranded DNA is rendered substantially single-stranded.

51. The method of Claim 50, wherein said treatment to render said double-stranded DNA is rendered substantially single-stranded by increasing the temperature.

52. The method of Claim 45, wherein said target nucleic acid comprises RNA.

53. A method of separating nucleic acid molecules, comprising:
a) providing:
i) a charge-balanced oligonucleotide and
ii) a reactant;
b) mixing said charge-balanced oligonucleotide with said reactant to create a reaction mixture under conditions such that a charge-unbalanced oligonucleotide is produced; and
c) separating said charge-unbalanced oligonucleotide from said reaction mixture.

54. The method of Claim 53, wherein said reactant comprises a cleavage means.

55. The method of Claim 54, wherein said cleavage means is an endonuclease.

56. The method of Claim 54, wherein said cleavage means is an exonuclease.

57. The method of Claim 53, wherein said reactant comprises a polymerization means.

58. The method of Claim 53, wherein said reactant comprises a ligation means.

59. The method of Claim 53, wherein said charge-balanced oligonucleotide comprises a label.

60. The method of Claim 53, wherein said charge-balanced oligonucleotide comprises one or more phosphonate groups.

61. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net neutral charge and said charge-unbalanced oligonucleotide has a net positive charge.

62. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net neutral charge and said charge-unbalanced oligonucleotide has a net negative charge.

63. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net negative charge and said charge-unbalanced oligonucleotide has a net positive charge.

64. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net negative charge and said charge-unbalanced oligonucleotide has a net neutral charge.

65. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net positive charge and said charge-unbalanced oligonucleotide has a net neutral charge.

66. The method of Claim 53, wherein said charge-balanced oligonucleotide has a net positive charge and said charge-unbalanced oligonucleotide has a net negative charge.

67. The method of Claim 54, wherein said charge-balanced oligonucleotide comprises DNA containing one or more positively charged adducts.

68. The method of Claim 67, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net positive charge.

5 69. The method of Claim 67, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net neutral charge.

10 70. The method of Claim 67, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net negative charge.

71. The method of Claim 54, wherein said charge-balanced oligonucleotide comprises DNA containing one or more negatively charged adducts.

15 72. The method of Claim 71, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net negative charge.

20 73. The method of Claim 71, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net neutral charge.

25 74. The method of Claim 71, wherein said cleavage means removes one or more nucleotides from said charge-balanced oligonucleotide to produce said charge-unbalanced oligonucleotide, wherein said charge-unbalanced oligonucleotide has a net negative charge.

30 75. The method of Claim 67, wherein said one or more positively charged adducts are selected from the group consisting of indodicarbocyanine dyes, amino-substituted nucleotides, ethidium bromide, ethidium homodimer, (1,3-propanediamino)propidium, (diethylenetriamino)propidium, thiazole orange, (N-N'-tetramethyl-1,3-propanediamino)propyl thiazole orange, (N-N'-tetramethyl-1,2-ethanediamino)propyl thiazole orange, thiazole orange-thiazole orange homodimer (TOTO), thiazole orange-thiazole blue heterodimer (TOTAB),

thiazole orange-ethidium heterodimer 1 (TOED1), thiazole orange-ethidium heterodimer 2 (TOED2) and fluorescein-ethidium heterodimer (FED).

5 76. The method of Claim 53, wherein said separating comprises subjecting said reaction mixture to an electrical field comprising a positive pole and a negative pole under conditions such that said charge-unbalanced oligonucleotide migrates toward said positive pole.

10 77. The method of Claim 53, wherein said separating comprises subjecting said reaction mixture to an electrical field comprising a positive pole and a negative pole under conditions such that said charge-unbalanced oligonucleotide migrates toward said negative pole.

15 78. The method of Claim 76 further comprising detecting the presence of said separated charge-unbalanced oligonucleotide.

79. A composition, comprising:

- 20 a) a first single continuous strand of nucleic acid, having a first and a second portion, comprising a sequence defining the template strand of a protein binding region;
- b) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to said first portion of said protein binding region;
- 25 c) a third single continuous strand of nucleic acid having a 5' and a 3' end, said third nucleic acid comprising a region complementary to said second portion of said protein binding region; and
- wherein said second and said third nucleic acids are annealed to said protein binding region such that a complete double-stranded protein binding region is formed.

30 80. The composition of Claim 79, wherein said protein binding region is a template-dependent RNA polymerase binding region.

81. The composition of Claim 80, wherein said RNA polymerase binding region is the T7 RNA polymerase binding region.

5 82. The composition of Claim 79, wherein said annealed second and said third nucleic acids are further annealed to one another.

83. The composition of Claim 82, wherein said second nucleic acid comprises a single-stranded 3' tail that is not capable of annealing to said first nucleic acid.

10 84. The composition of Claim 82, wherein said third nucleic acid comprises a single-stranded 5' tail that is not capable of annealing to said first nucleic acid.

85. The composition of Claim 79, wherein at least one of said second and said third nucleic acids comprises a region that is not annealed to said first nucleic acid.

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86. The composition of Claim 85, wherein said second nucleic acid comprises a single-stranded 3' tail that is not annealed to said first nucleic acid.

20 87. The composition of Claim 7, wherein said third nucleic acid comprises a single-stranded 5' tail that is not annealed to said first nucleic acid.

88. A method of producing RNA transcripts, comprising:
a) providing a composition comprising:
i) a first single continuous strand of nucleic acid comprising a
25 sequence defining the template strand of an RNA polymerase binding region;
ii) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to a first portion of said first nucleic acid;
iii) a third single continuous strand of nucleic acid having a 5' and a
30 3' end, said third nucleic acid comprising a region complementary to a second portion of said first nucleic acid; and

wherein said second and said third nucleic acids are annealed to said first nucleic acid such that a complete double-stranded RNA polymerase binding region is formed; and

- b) exposing said composition to conditions such that transcription occurs.

89. The method of any of Claims 25, 26, 29, 35-38 and 41-43, wherein said detecting said non-target cleavage products comprises:

- 5 a) providing:
- i) said non-target cleavage products;
 - ii) a composition comprising two single-stranded nucleic acids annealed so as to define a single-stranded portion of a protein binding region;
 - iii) a nucleic acid producing protein;
- 10 b) exposing said non-target cleavage products to said single-stranded portion of said protein binding region under conditions such that said nucleic acid producing protein binds to said protein binding region and produces nucleic acid.

90. The method of Claim 89, wherein said single-stranded portion of said protein binding region comprises:

- 15 a) a first single continuous strand of nucleic acid comprising a sequence defining the template strand of an RNA polymerase binding region; and
- b) a second single continuous strand of nucleic acid having a 5' and a 3' end, said second nucleic acid comprising a region complementary to a portion of said first nucleic acid, wherein said second nucleic acid is annealed to said first nucleic acid
- 20 so as to define said single-stranded portion of said protein binding region.

91. The method of Claim 90, wherein said protein binding region is a template-dependent RNA polymerase binding region.

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92. The method of Claim 91, wherein said template-dependent RNA polymerase binding region is the T7 RNA polymerase binding region.

93. The method of any of Claims 25, 26, 29, 35-38 and 41-43, wherein said detecting said non-target cleavage products comprises:

- 30 a) providing:
- i) said non-target cleavage products;

- ii) a single continuous strand of nucleic acid comprising a sequence defining a single strand of an RNA polymerase binding region;
 - iii) a template-dependent DNA polymerase;
 - iv) a template-dependent RNA polymerase;
- 5 b) exposing said non-target cleavage products to said RNA polymerase binding region under conditions such that said non-target cleavage product binds to a portion of said single strand of said RNA polymerase binding region;
- c) exposing said bound non-target cleavage product to said template-dependent DNA polymerase under conditions such that a double-stranded RNA
- 10 polymerase binding region is produced;
- d) exposing said double-stranded RNA polymerase binding region to said template-dependent RNA polymerase under conditions such that RNA transcripts are produced.
- 15 94. The method of Claim 93 further comprising detecting said RNA transcripts.
95. The method of Claim 93, wherein said template-dependent RNA polymerase is the T7 RNA polymerase.

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MAJORITY	ATGXXGGCCCATGCTTCCCGCTCTTTGAGGCCAAAGCCCGCGTCCCTCGTGGAGCGGCCACGACCTGGCGCT	
DISPUTAO	AG..G.....G.....	70
DISPUTR	.....G.....G.....	67
DISPUTH	CA.....G.....A.....	70
MAJORITY	ACCGCCACCGTTCTTCGGCCGCTGAAGGGCCCTCACCACGACCGCGCGGCGCAACCGGTCGAGGGCGGCTCAGCGGCTT	
DISPUTAO	.....CA.....G.....G.....	140
DISPUTR	.....T.....G.....C.....C.....T.....	137
DISPUTH	.....G.....G.....	140
MAJORITY	CCCCAAGAGCCCTCCCTCAAGGCCCTCAAGGAGGACGGCGGACXXGGCGGGTGTCTGGTCTTTGACGGCCAAAG	
DISPUTAO	.....C.....A.....	207
DISPUTR	A.....GT.....T.....	204
DISPUTH	.....T.....AA.....C.....CT.....	210
MAJORITY	GGCGCGCTCCCTCCGCGCCACGAGGGCTACGAGGGCTACAAGCGCGCGCGCGCGCGCGCGCGGAGGAGCTTTC	
DISPUTAO	.....G..GG.....G.....	277
DISPUTR	.....GA.....G.....C.....	274
DISPUTH	.....G.....G.....C.....	280
MAJORITY	CCCCCGCAGCTCGCGCTCATCAAGGAGGCTGCTCGACCTCCTCGCGCTTCCCGCGCTTCGAGGCTCCCGCGGCTA	
DISPUTAOA.....T.....G.....G.....	347
DISPUTRG.....T.....A.....C.....T.....G.....G.....T.....	344
DISPUTHT.....T.....A.....C.....	350

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Fig. 18

SEQUENCE	CGAGCGGACGACGCTXCTGGCCACCCCTGGCCCAAGAGCGGCAAAAGGAGCGGCTACGAGGTCGGCGATCCCTC	417
SEQUENCE	.....C.....G.....C.....C.....	414
SEQUENCE	.....G.....CG.....	420
SEQUENCE	.....T.....C.....	
SEQUENCE	ACCGCGGACGCGGACCGTCTACCGAGGTCCTTTCGGACCGGATCGCCGTCCTCCACCCCGAGGGGTACCTCA	487
SEQUENCE	.....AAA.....T.....CA.....	484
SEQUENCE	.....T.....G.....G.....A.....T.....C.....	490
SEQUENCE	.....A.....G.....G.....G.....CC.....	
SEQUENCE	TCACCCCGCGGCTGGCTTTCGGAGAGGTACCGGCTGAGCGCGGAGCGAGTGGGTGGACTACCGCGCGGCTGGC	557
SEQUENCE	.....G.....A.....C.....C.....CC.....A.....	554
SEQUENCE	.....AC.....CG.....C.....C.....T.....C.....C.....	560
SEQUENCE	.....A.....C.....C.....T.....C.....C.....	
SEQUENCE	GGCGGACCGGCTCCGACAAACCTTCCCGCGGGGTCAAGGGGCTCGCGGAGAGACCGCGGCTCGAGGCTCCTCXAG	627
SEQUENCE	.....GAG.....T.....G.....GAG.....T.....CG.....	624
SEQUENCE	.....G.....T.....A.....G.....A.....G.....A.....CGC.....	630
SEQUENCE	.....C.....T.....A.....G.....TC.....A.....	
SEQUENCE	GAGTCGGCGGAGCGCTCGGAAAAACCTCCTCAAGAACCTGGACCGGGGTGAAGCGCGCG.....CXTCCGGGACAGAGA	694
SEQUENCEGC.....C.....A.....	691
SEQUENCET.....C.....C.....T.....T.....G.....C.....	700
SEQUENCEA.....A.....A.....A.....A.....A.....A.....	

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Fig 1C

SEQUENCE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102	1103	1104	1105	1106	1107	1108	1109	1110	1111	1112	1113	1114	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124	1125	1126	1127	1128	1129	1130	1131	1132	1133	1134	1135	1136	1137	1138	1139	1140	1141	1142	1143	1144	1145	1146	1147	1148	1149	1150	1151	1152	1153	1154	1155	1156	1157	1158	1159	1160	1161	1162	1163	1164	1165	1166	1167	1168	1169	1170	1171	1172	1173	1174	1175	1176	1177	1178	1179	1180	1181	1182	1183	1184	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296	1297	1298	1299	1300	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1323	1324	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335	1336	1337	1338	1339	1340	1341	1342	1343	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363	1364	1365	1366	1367	1368	1369	1370	1371	1372	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397	1398	1399	1400	1401	1402	1403	1404	1405	1406	1407	1408	1409	1410	1411	1412	1413	1414	1415	1416	1417	1418	1419	1420	1421	1422	1423	1424	1425	1426	1427	1428	1429	1430	1431	1432	1433	1434	1435	1436	1437	1438	1439	1440	1441	1442	1443	1444	1445	1446	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461	1462	1463	1464	1465	1466	1467	1468	1469	1470	1471	1472	1473	1474	1475	1476	1477	147
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[illegible]

FIG. 1E

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SEQUENCE	GGAGATCCGCGCGCTCGAGGAGGAGGTCTTCGGGCTTGGCGGCGCCACCCCTTCAACCTCAACTCCCGGGAC	1464
SEQUENCE	.....CC.....	1461
SEQUENCE	..G..G..AG..G..	1470
SEQUENCE	.....T.....G.....	
SEQUENCE	CAGCTGGAAAGGGTCTCTTCAGGAGGCTXGGGGCTTCGGGCGCATCGGCAAGACGGAGAGACXGGCAAGC	
SEQUENCE	.....G.....A.....	1534
SEQUENCE	.....G.....G..C..G..T.....	1531
SEQUENCE	.....G.....TA.....T..G..G.....C..A.....	1540
SEQUENCE	GGTCCACGAGCGCGCGCGCTGCTCGAGGGCGCTXCGXGAGGGCGCCACCCCATCGTGGAGAGAGATCCTGCAGTA	
SEQUENCE	.....C.....G..C.....	1604
SEQUENCE	.....T.....G..A.....CGGC.....	1601
SEQUENCE	.....G.....A..G.....C.....C.....	1610
SEQUENCE	CCGGGAGGCTCACCAGGCTCAAGAGACAGCTACATXGAGCGCGCTGCCXGCGCTCGTCCACCCCGAGACCGGC	
SEQUENCE	.....G.....G.....T.....T.....G..A.....A.....	1674
SEQUENCE	.....G.....A.....C..C.....G.....A.....C.....	1671
SEQUENCE	.....G.....G.....C..AAG.....G.....	1680
SEQUENCE	CGGCTCCACACCGCGCTTCAACGAGACGGCGCAGCGCGCGCGCTAGTAGCTCCGACCCCAACCTGC	
SEQUENCE	.....G.....C.....A.....T.....C.....	1744
SEQUENCE	.....G.....C.....TCC.....	1741
SEQUENCE	.....G.....G.....	1750

FIG. 1F

MAJORITY	AGACATCCCCGTCCGACCCXCTGGGCCAGAGCAATCCGCCCGGGCCITCGTGGCCGAGGAGCGGTGGGT	
ORF1A0	.....G..T..G.....A..G.....G...C..	1814
ORF1A1	.....G.....T.....C..C.....A.....C.....	1811
ORF1A2	.....CT.....CT.....C...T...C	1820
MAJORITY	GTGGTGGGGCTGGACTATAGCCAGATAGAGCTCGGGGTGCTGGCCCACTCTCCGGCGAGGAGACCTG	
ORF1A0	A.....I..T.....C.....T.....A.....G.....C.....	1884
ORF1A1	.....I..T.....C.....T.....T.....C.....	1881
ORF1A2	.....C.....G.....G.....C.....A.....	1890
MAJORITY	ATCCGGGTCTTCCAGGAGGGGAGGACATCCACACCCAGAGCCGCGAGCTGGATCTTCCGGCGTCCCCCGGG	
ORF1A0	.....G.....C.....GG.....G...G...G...	1954
ORF1A1	.....T.....A.....A.....T...T...C..	1951
ORF1A2	.....A.....A.....A.....C.....	1960
MAJORITY	AGGGCGTGGACCCCTGATGGCGCGGGGGCCCAAGACCATCAACTTCGGGGTCCCTCTACGGCATGTCCCG	
ORF1A0	.....A..G..A.....T.....G.....G...G...	2024
ORF1A1	.....GG.....GG..G.....G.....	2021
ORF1A2	.....GG.....GG..G.....G.....	2030
MAJORITY	CCAGCGGCTCTCCAGGAGCTTCCCATCCCTACGAGGAGGCGGTGGCCCTTCATTGAGCGGCTACTCCAG	
ORF1A0A.....T.....CCA.....T...T...	2094
ORF1A1GG.....T.....C.....C.....	2091
ORF1A2TA..G.....T.....T...A.....A	2100

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FIG. 1G

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MAJORITY	AGCTTCCCCCAAGGTGCGGGCCCTGGATTGAGAAAGACCCCTGGAGGAGGGCGAGGCGGGGGGTACGTCGAGCA	2164
DISPTAO	.....	2161
DISPTR	.....A.....	2170
DISPTH	.....A.....A.....G.....C.....A.....C.....	
MAJORITY	CCCTCTTCGGCGCGCGCGCGGTACGTGCGCGACCTCAACGCGCGCGCGGTGAACAGCCGTCGCGGAGGCGCGCGGA	
DISPTAO	.....C.....A.....AG.G.....	2234
DISPTR	.....T.....	2231
DISPTH	.....AA.AA.....	2240
MAJORITY	GGCGATGGCCCTTCAACATGCCCGTCCAGGGCACCGCGCGGAGCCTCATCAAGCTGCCCATGGTCAGGCTC	
DISPTAO	.....	2304
DISPTR	.....G.....	2301
DISPTH	.....	2310
MAJORITY	TTCCCGCGCGCTXCAGGAAATCGGGGCGCAGGATGCTCCCTXCAGGTCACGACGAGCGTGGTCCTCGAGGCGCG	
DISPTAO	.....A.....GG.....	2374
DISPTR	.....T.....C.....G.....TT.G.....G.....	2371
DISPTH	.....C..C.G..G.....C..C.....C.....CC.....G.....	2380
MAJORITY	CCAAAGAGCGCGCGCGGAGGCGGTGGCGCGCTTGGCCCAAGGAGGTCATCGAGGGGCGTCTATCCCGTCCCGCT	
DISPTAOA.....A.....CC.....CGGC.....G.....	2444
DISPTRG..C.....AG...A.....	2441
DISPTHC..C.....C.....A.....G.....C.....AA..C.....C.....	2450

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FIG. 1H

SEQUENCE	CCCCCTGGAGGTGGAGGTGGGCGATGGGCGAGGACTGGCTCTCCCCAAGCAGTAG	2499
SEQUENCEA.....GA	2496
SEQUENCECC.....	2505
SEQUENCET.....GT...	

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FIG. 2A

SEQUENCE	MIXA ML PL FEPKGRVLLVDGHHLAYRTFFALKGLTISRCEPVOAVYGFAXSLKALKEDG·DAVXVVVFD·AK	
SEQ ID NO	RC·····H·····I·····	69
SEQ ID NO	·····V·····V·····	68
SEQ ID NO	·····YK·····F·····	70
SEQUENCE	APSF RHEAYEAYKAGRAPTPEDFPROLALIKELVDLLGLXRLEVPQYEADQVLATLAKKAEKEGYEVRIL	
SEQ ID NO	·····GG·····A·····S·····	139
SEQ ID NO	·····V·····F·····R·····	138
SEQ ID NO	·····FI·····	140
SEQUENCE	TADRDLYOLLSDRIAVLHPGYLITPAWLWEKYGLRPEQWVDYRALXGDPSONLPGVKGIGEXTAKLLX	
SEQ ID NO	·····K·····H·····D·····T·····E·····R·····E·····	209
SEQ ID NO	·····E·····I·····Y·····A·····I·····OR·····IR·····	208
SEQ ID NO	·····V·····H·····E·····F·····V·····L·····K·····	210
SEQUENCE	EWGSL EHL'KNLDRVVP·XXREKI XAHMEDLXLSXXLSXVRTDLPLEVDFAXRREPDRGLRAFLERLEF	
SEQ ID NO	·····A·····L·····A·····L·····D·····K·····WD·····AK·····R·····	278
SEQ ID NO	·····FOH·····O·····SL·····LQ·····G·····A·····RK·····O·····H·····GR·····T·····HL·····	277
SEQ ID NO	·····ENV·····K·····L·····R·····LE·····R·····L·····OG·····	280
SEQUENCE	GSLLHEFGLLXPKALEEAPWPPPEGAFVGFVLSRPEPMWAELLALAAARXGRVHRAXDPLXGLRDLKEV	
SEQ ID NO	·····S·····	348
SEQ ID NO	·····G·····A·····L·····SF·····D·····G·····WE·····L·····O·····R·····C·····	347
SEQ ID NO	·····A·····AP·····K·····C·····D·····A·····A·····K·····	350

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FIG. 28

SEQUENCE	RGLLAKDLAVLALREGLDLPDOPMLLAYLLOPSNTTPEGVARRYGGEWTEADAGERALLSERLFXNLXX	
SEQ ID NO 1	S.....G.P.....E.....A.....A.....WG	418
SEQ ID NO 2	I.....F.E.....A.....OT..KE	417
SEQ ID NO 3	S.....V.....AH.....HR..LK	420
SEQUENCE	RLEGEERLLWLYXEVEKPLSRVLAHMEATGVRLDVAYLOALSLEVAEEIRALEEEVFRLAGHPFHLNSRD	
SEQ ID NO 4	R.....R.....A.....R.....A.....A.....	488
SEQ ID NO 5	K.....E.....R.....EA.V.O.....	487
SEQ ID NO 6	K.....H.....L.....L.....	490
SEQUENCE	OLERVLFDELGLPAIGKTEKTGKRSTSAAVLEALREAHPIVEKILQYRELTCLKNTYIDPLXLVHPRTG	
SEQ ID NO 7	.....S.....D.I.....	558
SEQ ID NO 8	R.....L.....O.....DR.....A.....K.....	557
SEQ ID NO 9	.....V.....S.....	560
SEQUENCE	RLHTRFNQTATATGRLSSSDPNLOHLPVRTPLGQRIIRAFVAEEGWXLVALDYSOIELRVLAHLSGOENL	
SEQ ID NO 10	.....I.....L.....	628
SEQ ID NO 11	.....V.....V.....	627
SEQ ID NO 12	.....A.....A.....	630
SEQUENCE	IRVFQEGRDIHTOTASWFGUPPEAVDPLNRRAAKTIIRFGVLYGMSAHLRSOELAIPIYEEAVAFIERYFO	
SEQ ID NO 13	E.....R.....O.....	698
SEQ ID NO 14	S.....G.....G.....S.....	697
SEQ ID NO 15	K.....V.....	700

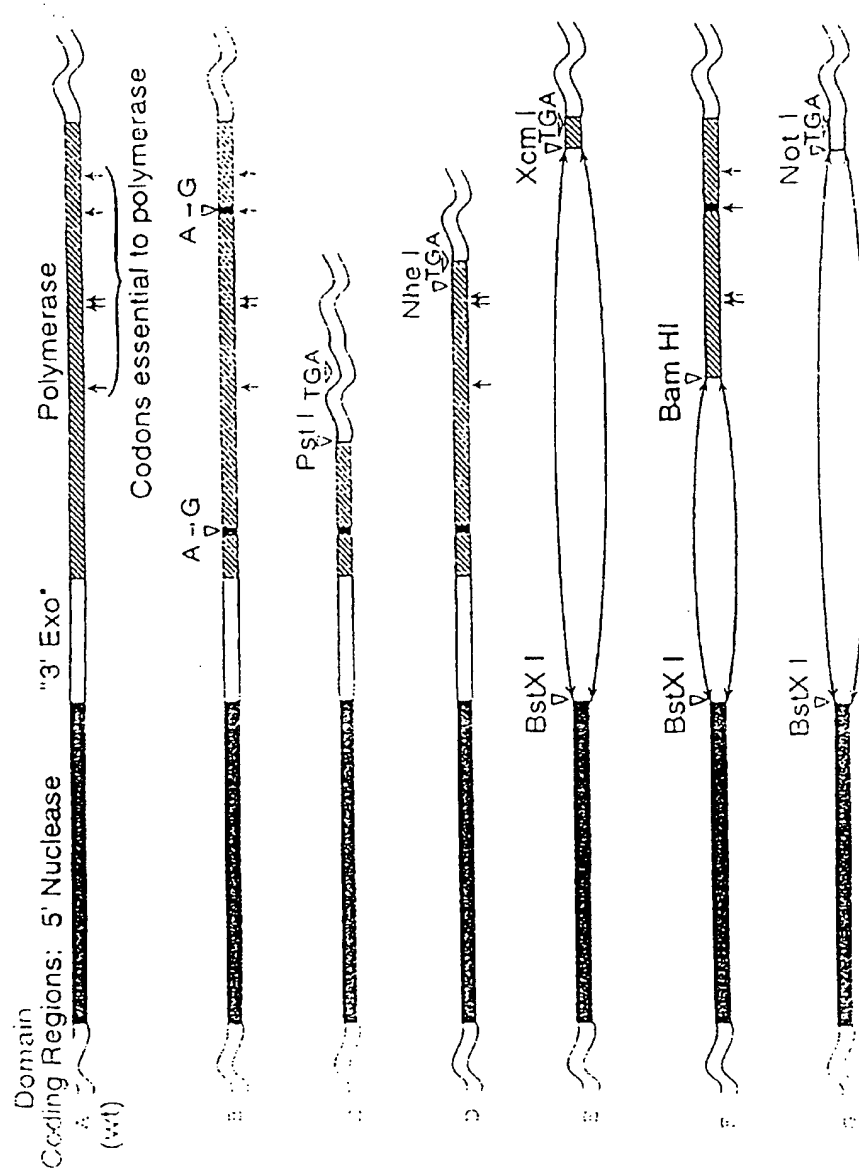
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FIG. 2C

SEQUENCE	SFPKURAWI EKTLEEGRRRGYVETLFCRRRYVDPOLNARUKSVREAAERMAFNMPVOGTAADLKKLMMVKL	768
120 P90	.....E.....	767
121 P90	Y.....G.....R.	770
122 P90	.....K.....	
SEQUENCE	FPRLXEMGARMILQVHDELVL EAPKXRAEXVAALAKEVNEGVYPLAVPLEVEVGXGEDWLSAKEX	
120 P90E.....A.....R.....	833
121 P90O.....L.....W.....O.....	831
122 P90R.....L.....DA.....E.....A.....KA.....M.....G.....	835

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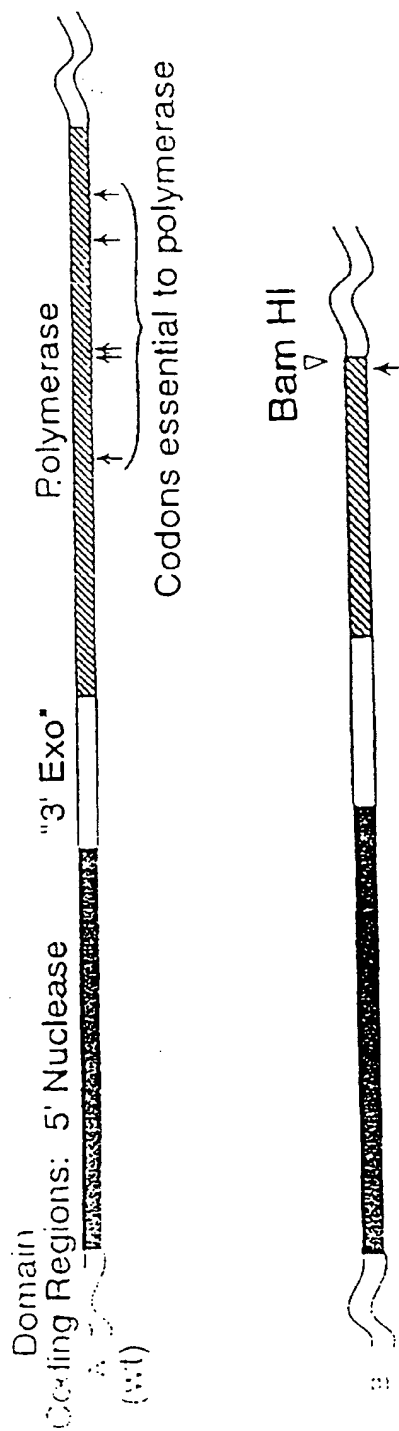
FIG. 3



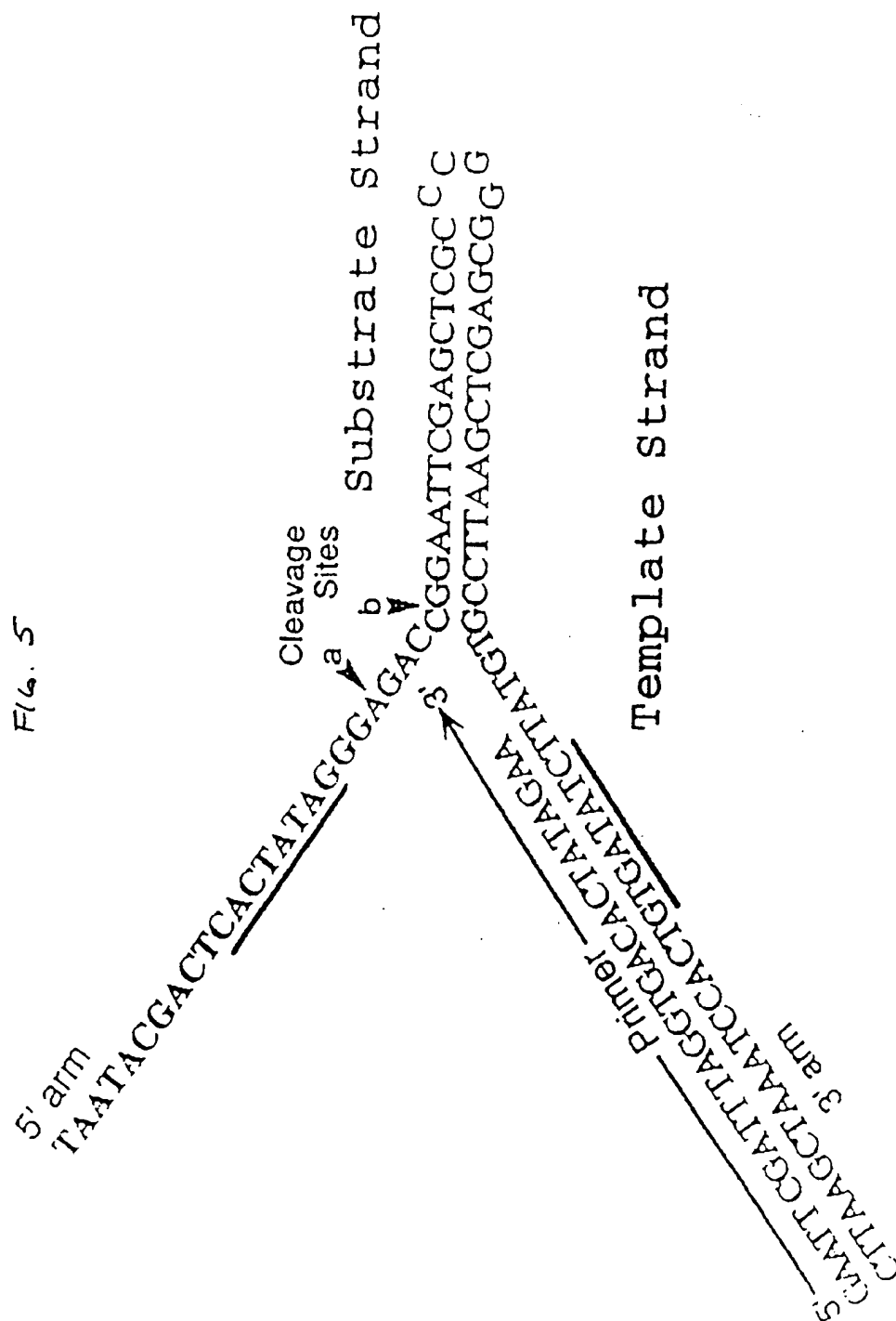
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FIG. 4

Genes for Wild-Type and Pol(-) DNAPTH



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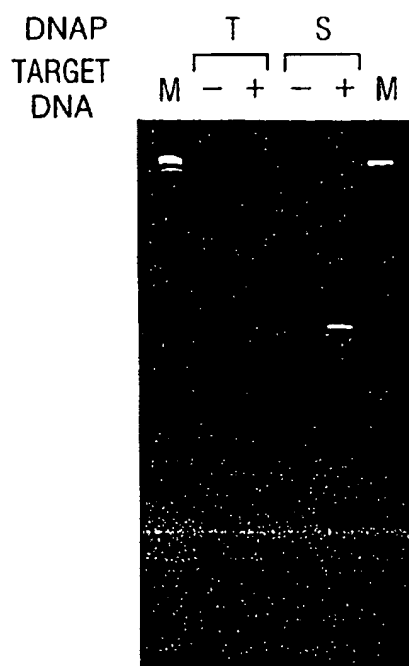


FIG. 6

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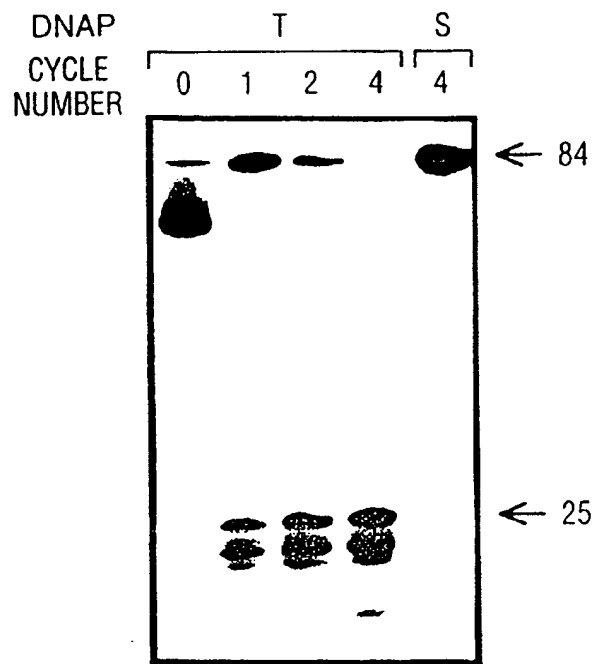


FIG. 7

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	1	2	3	4	5	6
DNAP-T:	-	+	+	+	+	+
MgCl ₂ :	+	-	+	+	+	+
dNTPs:	+	-	+	-	+	-
Primers:	+	-	+	+	-	-

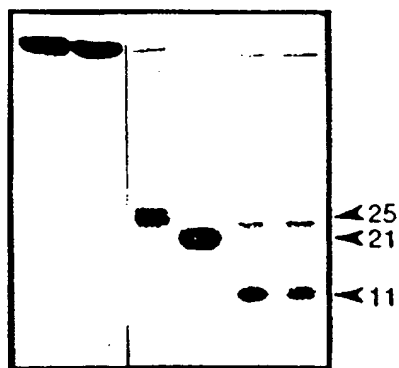


FIG. 8A



FIG. 8B

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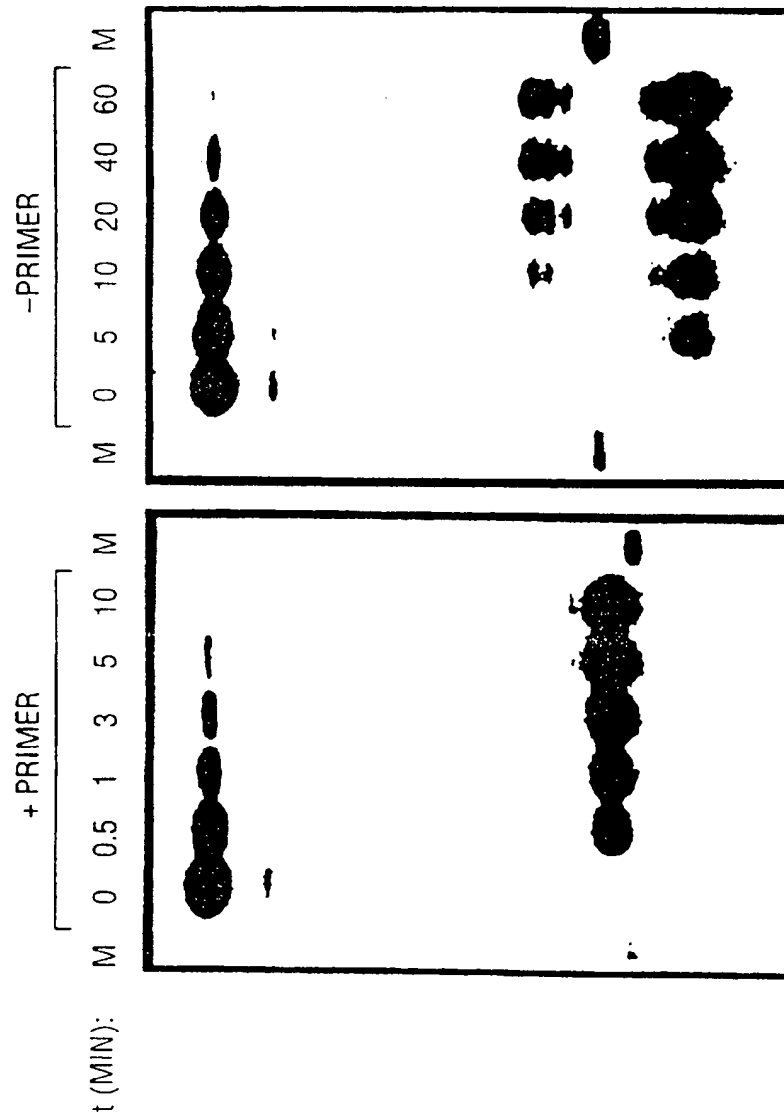


FIG. 9A

FIG. 9B

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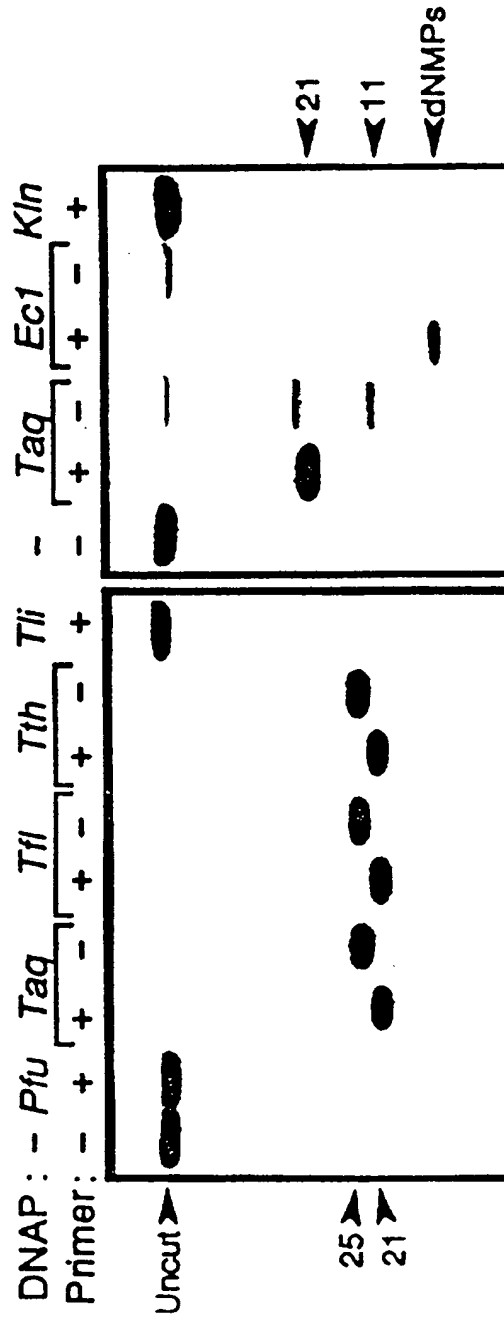
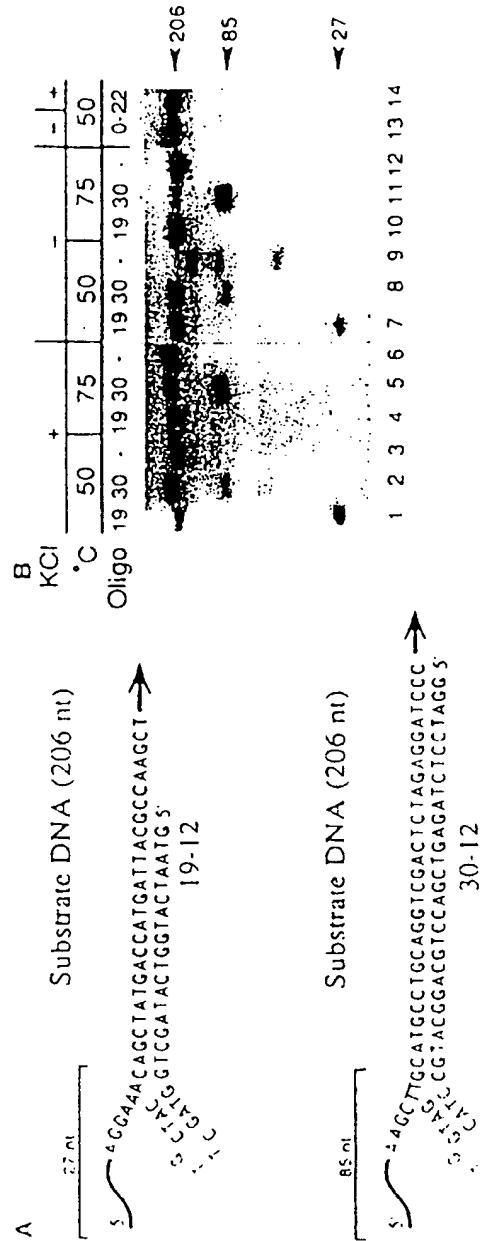


FIG. 10A

FIG. 10B

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FIGURE 11



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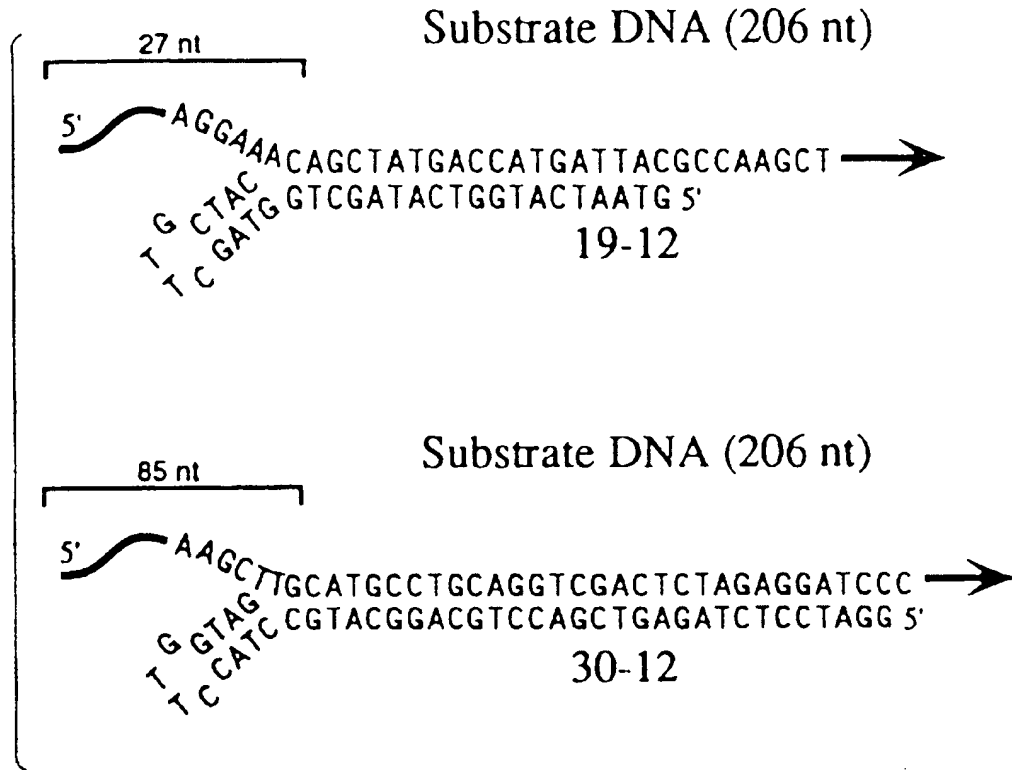


FIG. 11A

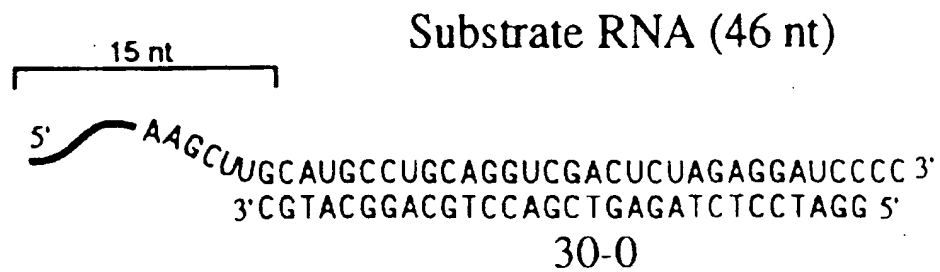


FIG. 12A

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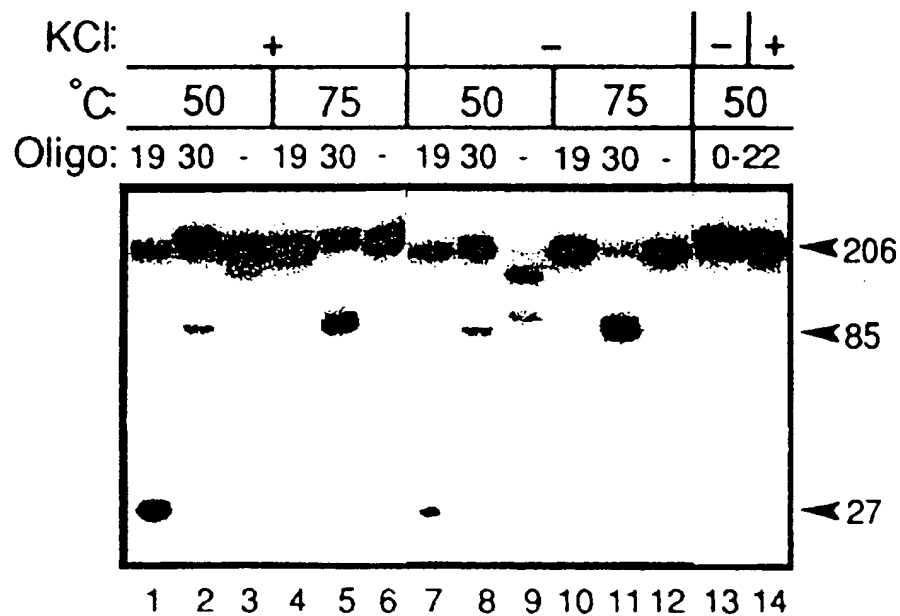


FIG. 11B

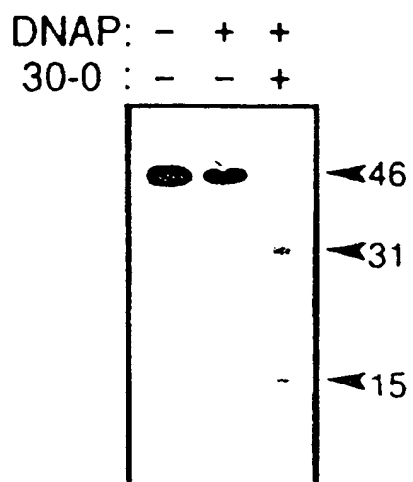
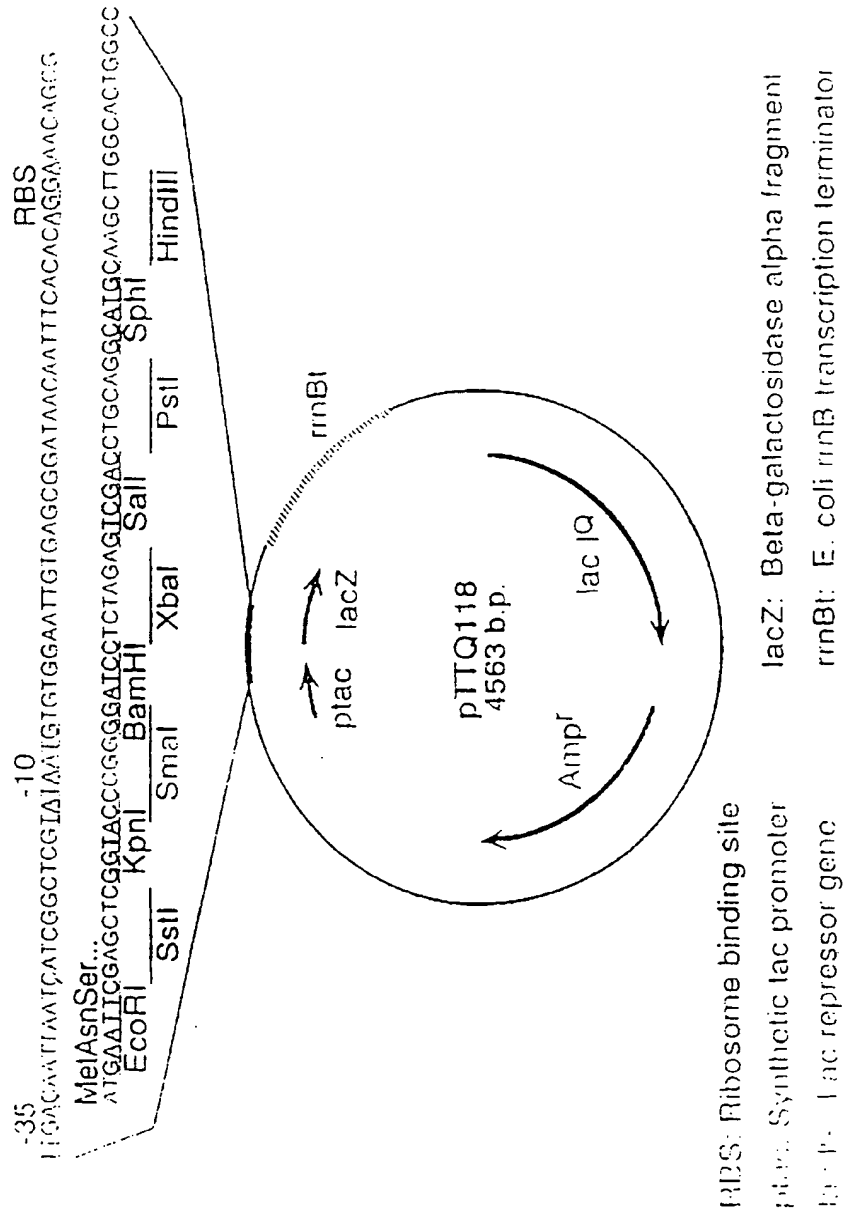


FIG. 12B

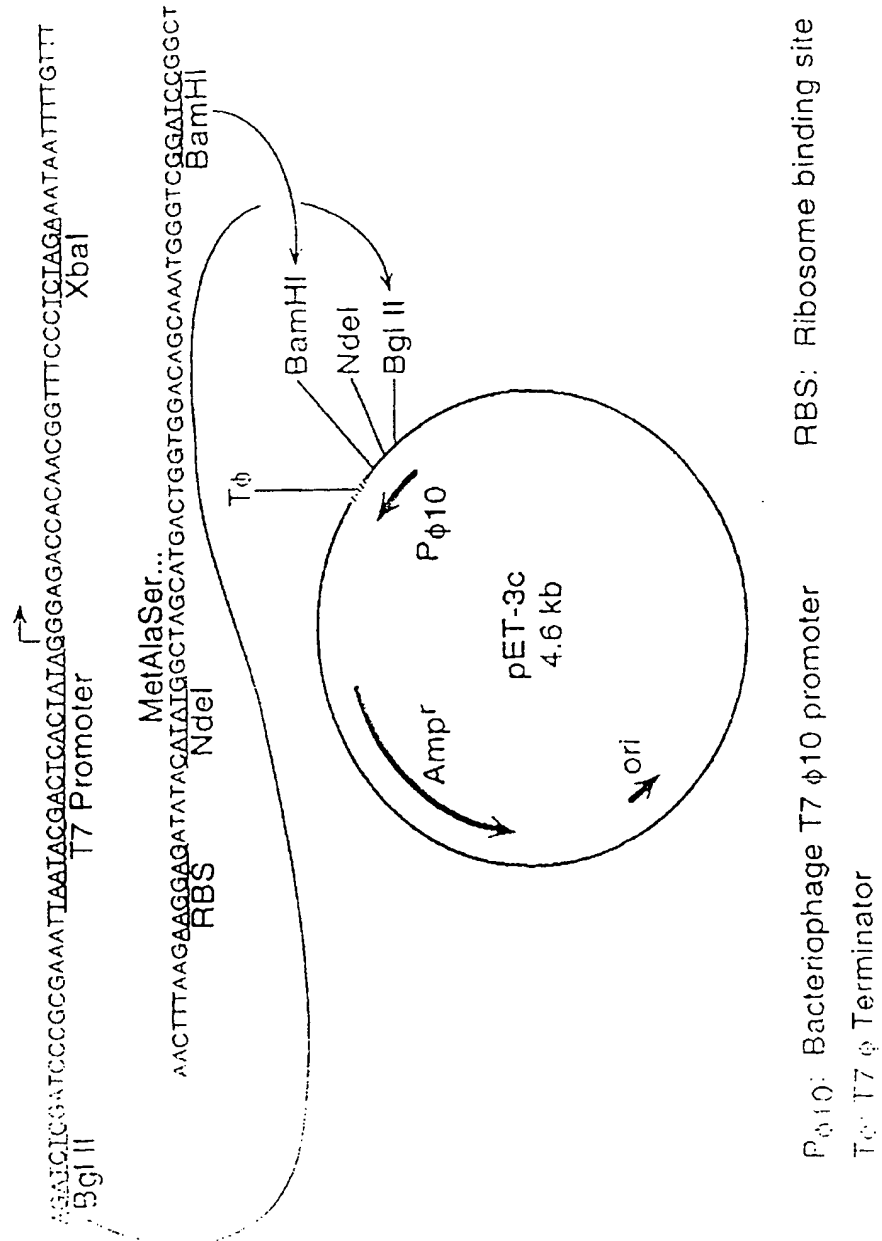
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FIGURE 13



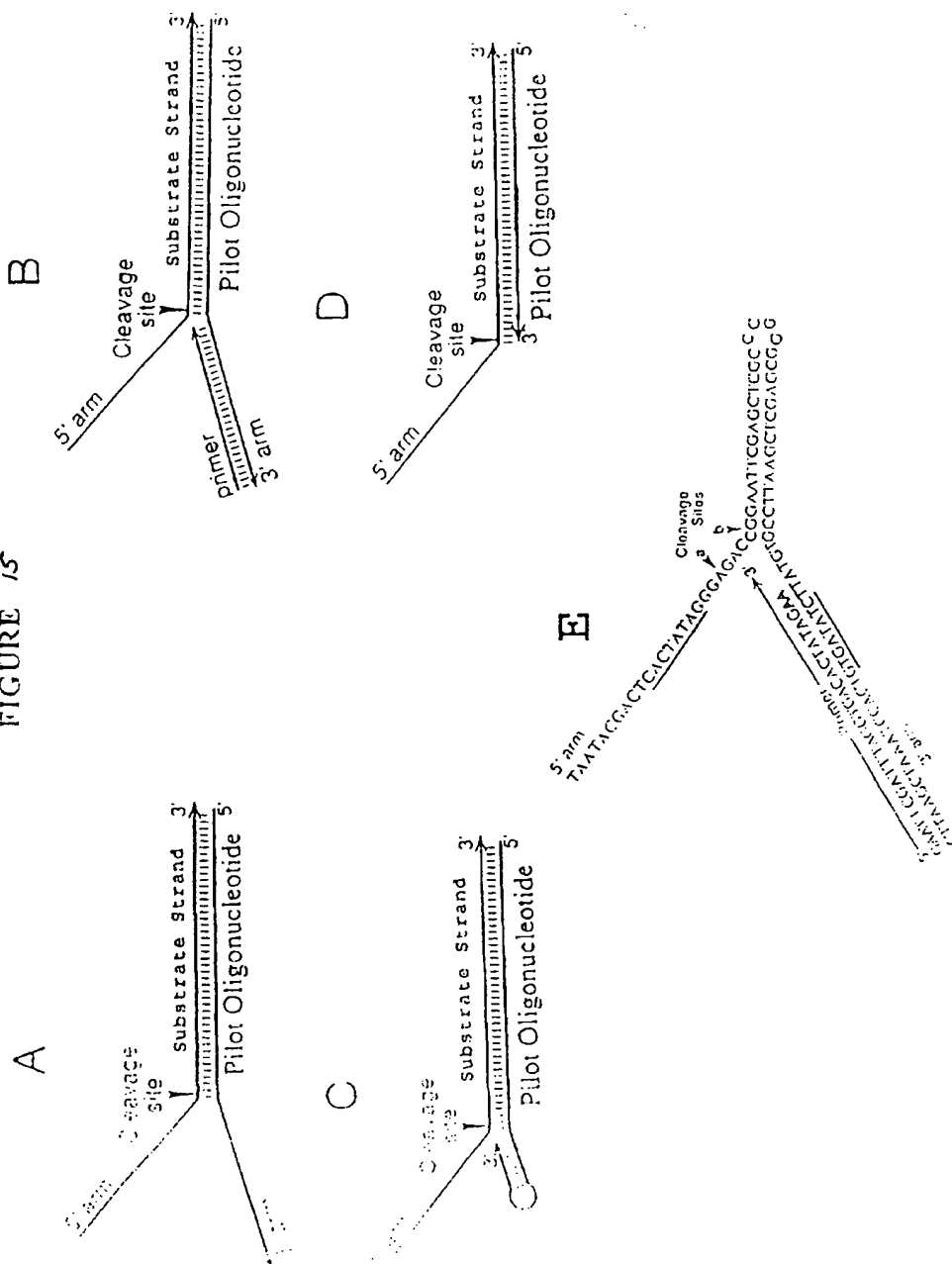
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FIGURE 14



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FIGURE 15



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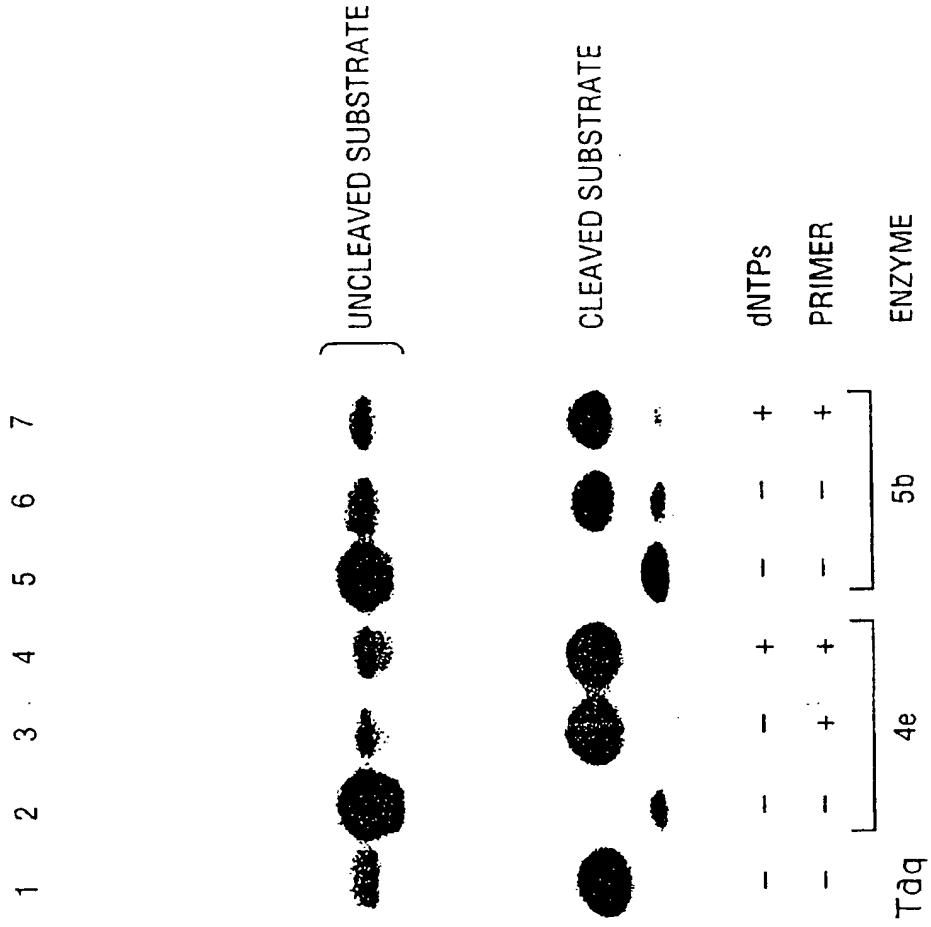


FIG. 14

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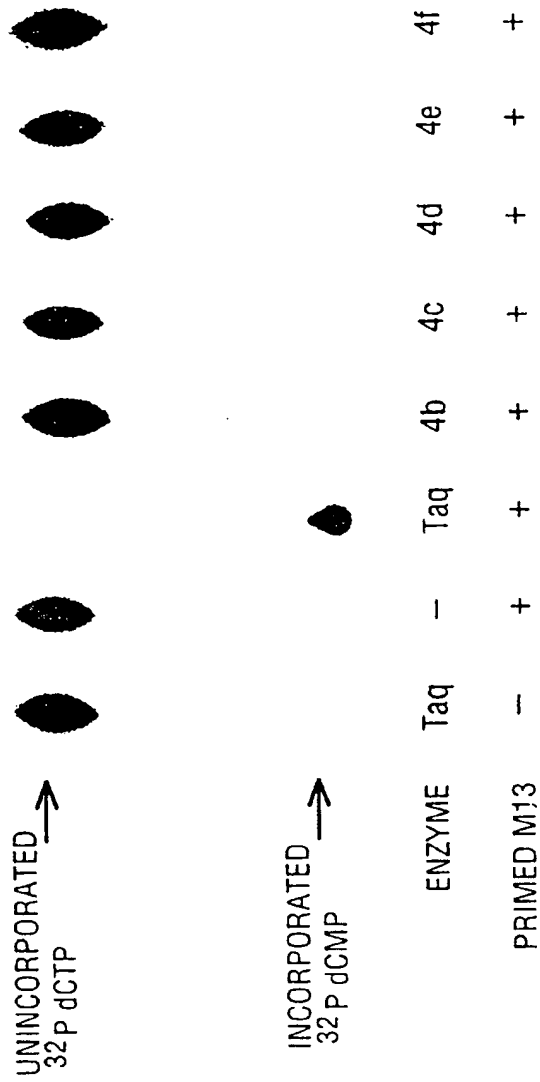


FIG. 17

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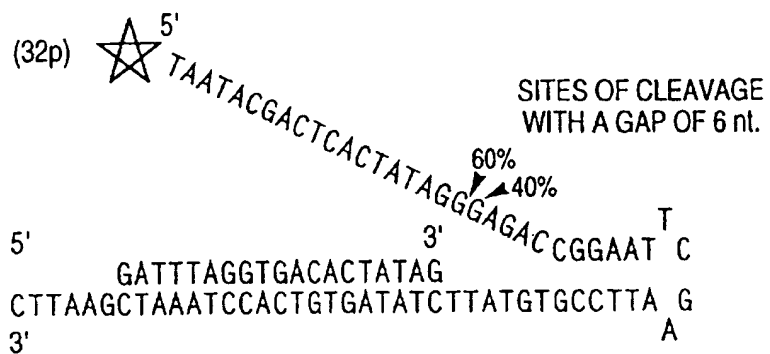
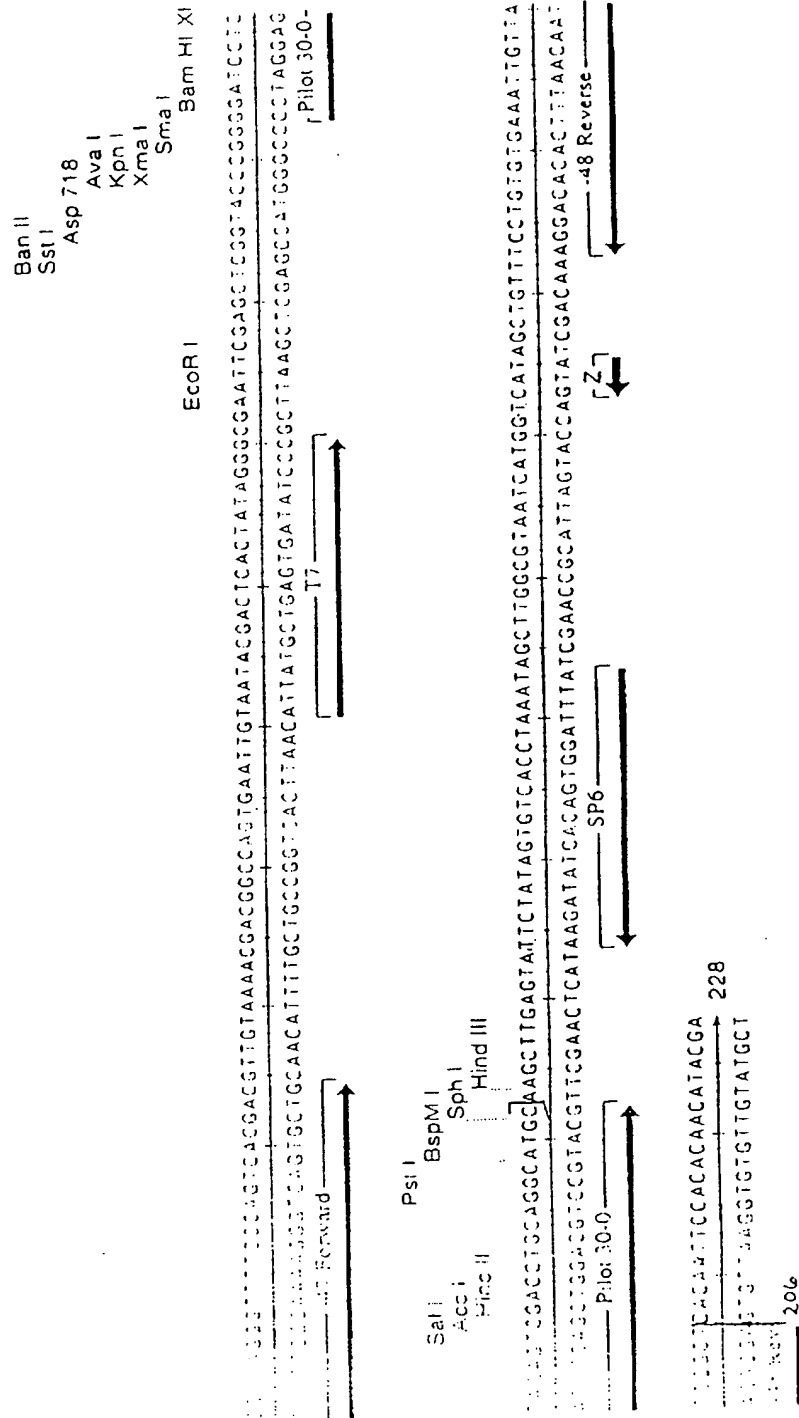


FIG. 18A

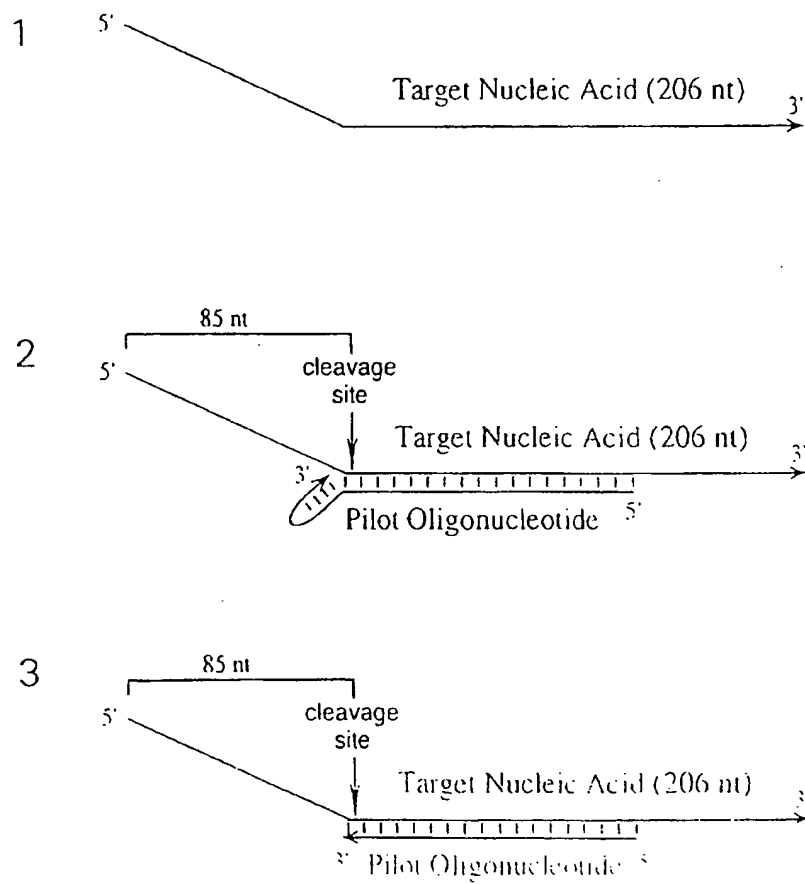
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FIGURE 19



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FIGURE 20A



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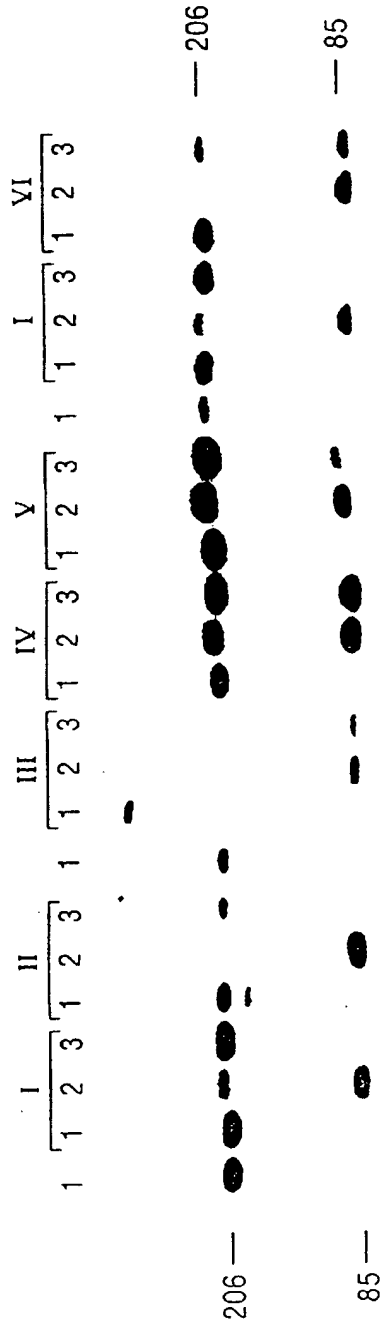


FIG. 208

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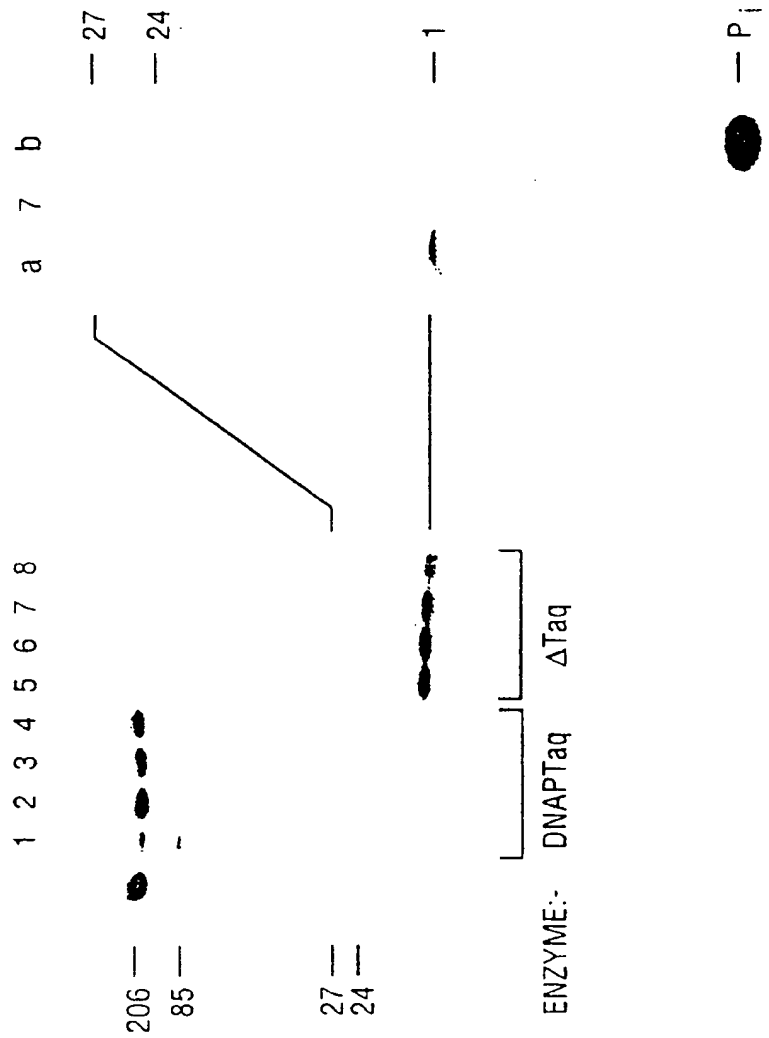


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FIG. 2/1A

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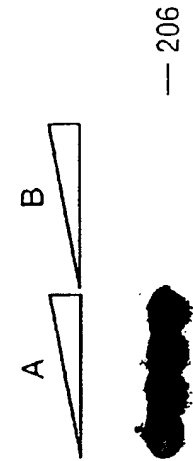


FIG. 22A

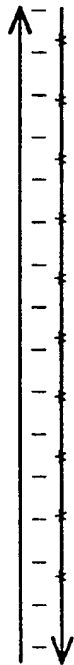
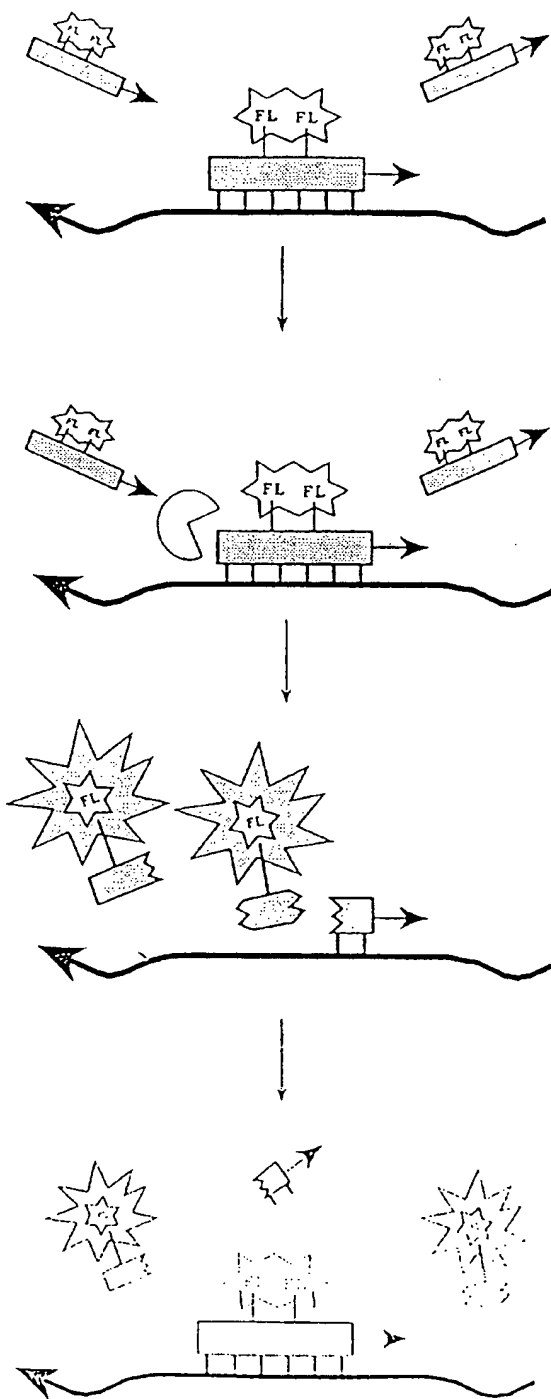


FIG. 22B

* = 32p

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FIGURE 23



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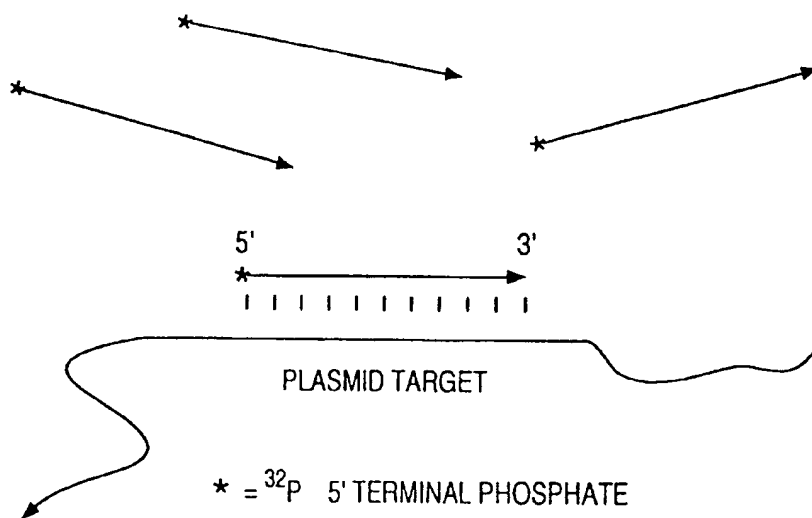


FIG. 24A

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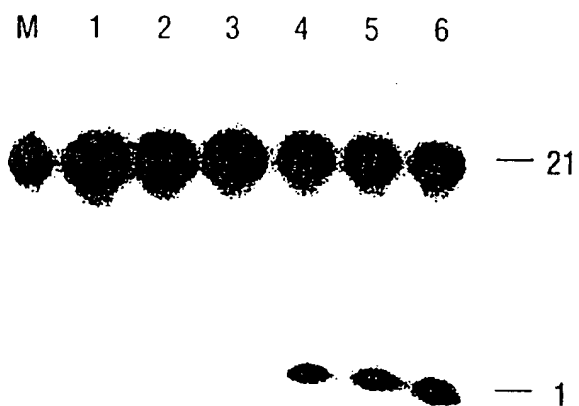


FIG. 24B

FIGURE 25

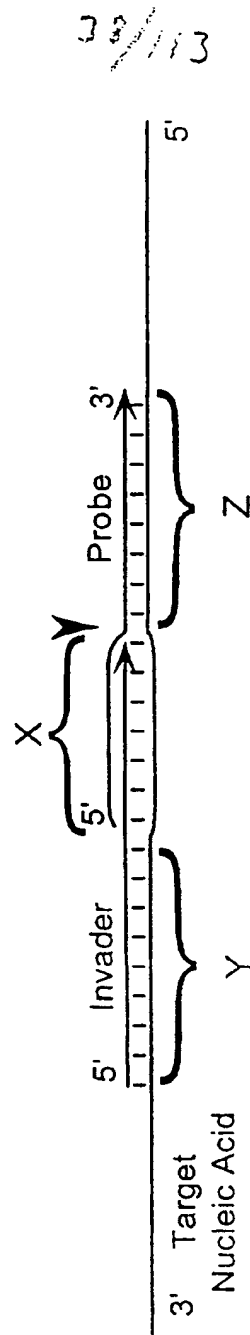


FIGURE 26

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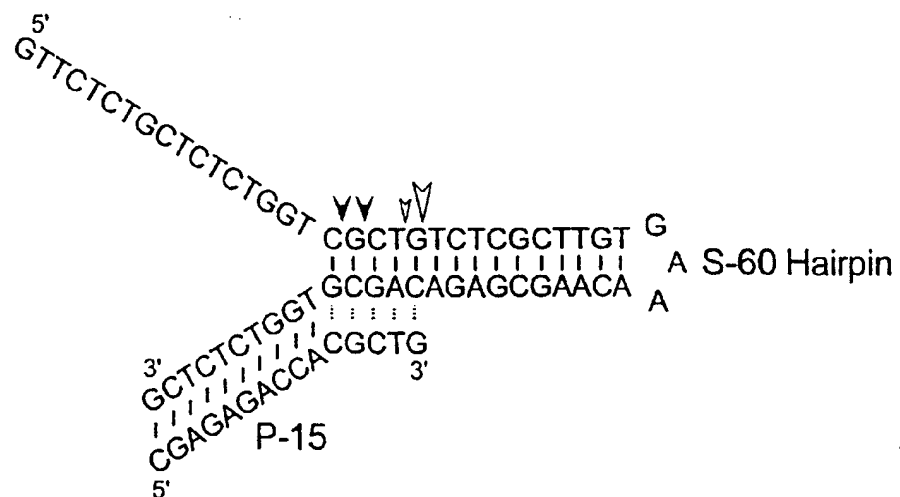


FIGURE 27

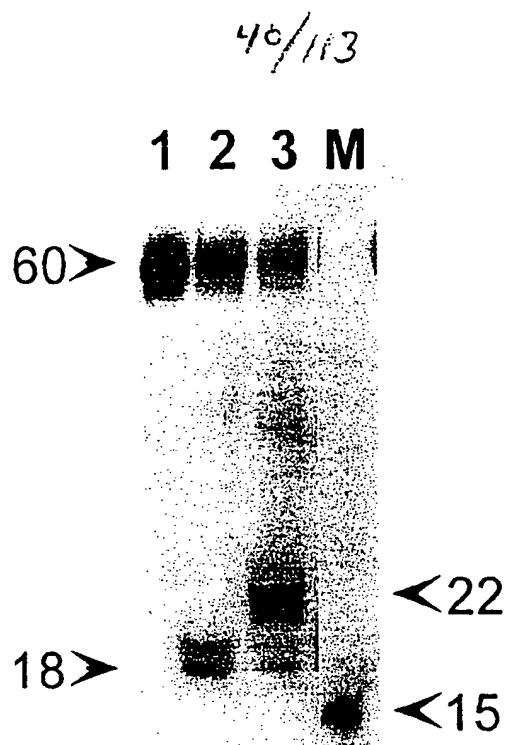
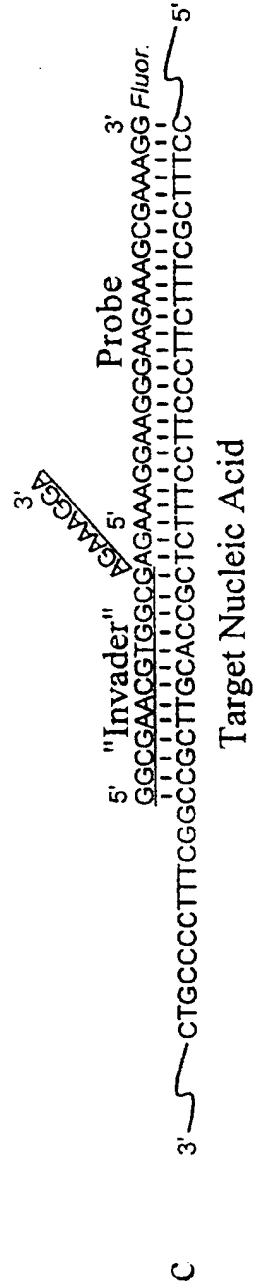
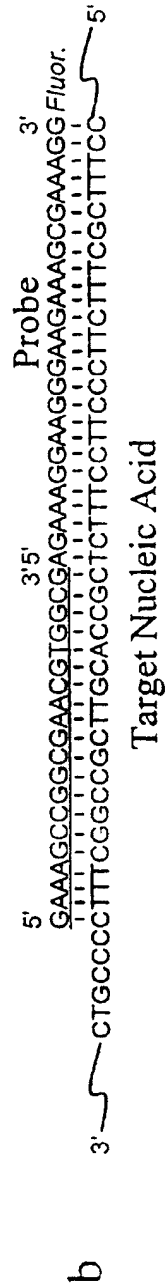
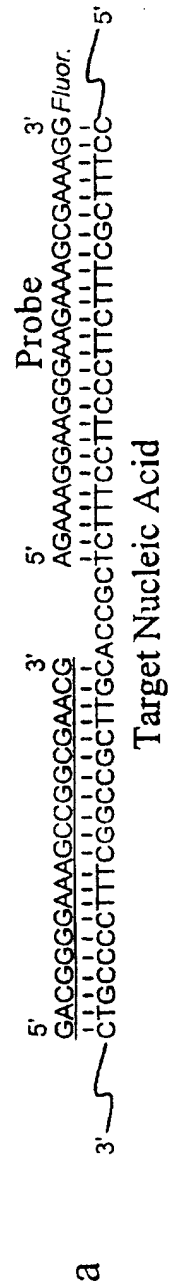
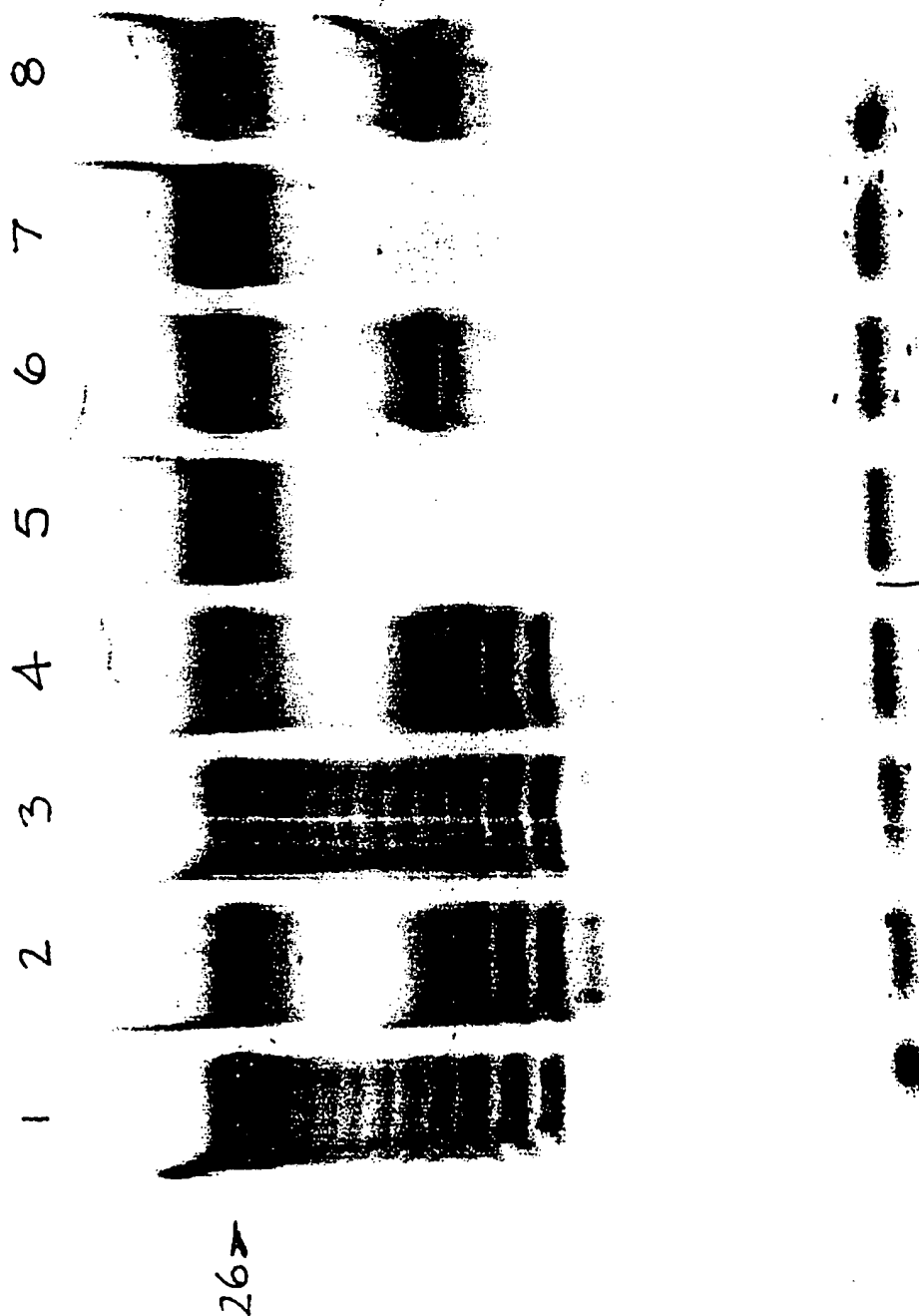


FIGURE 2a



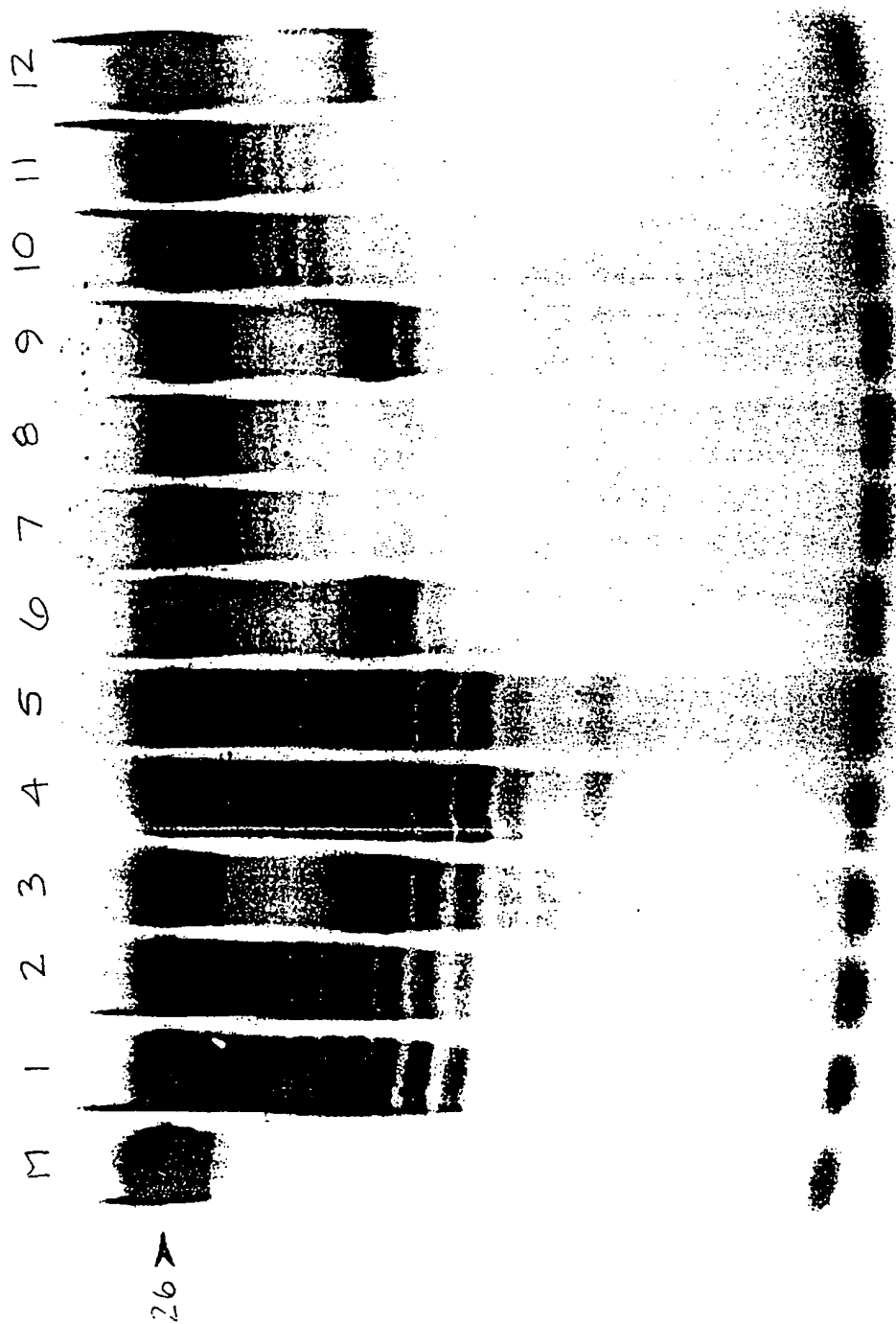
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FIGURE 29



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FIGURE 30



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FIGURE 3/

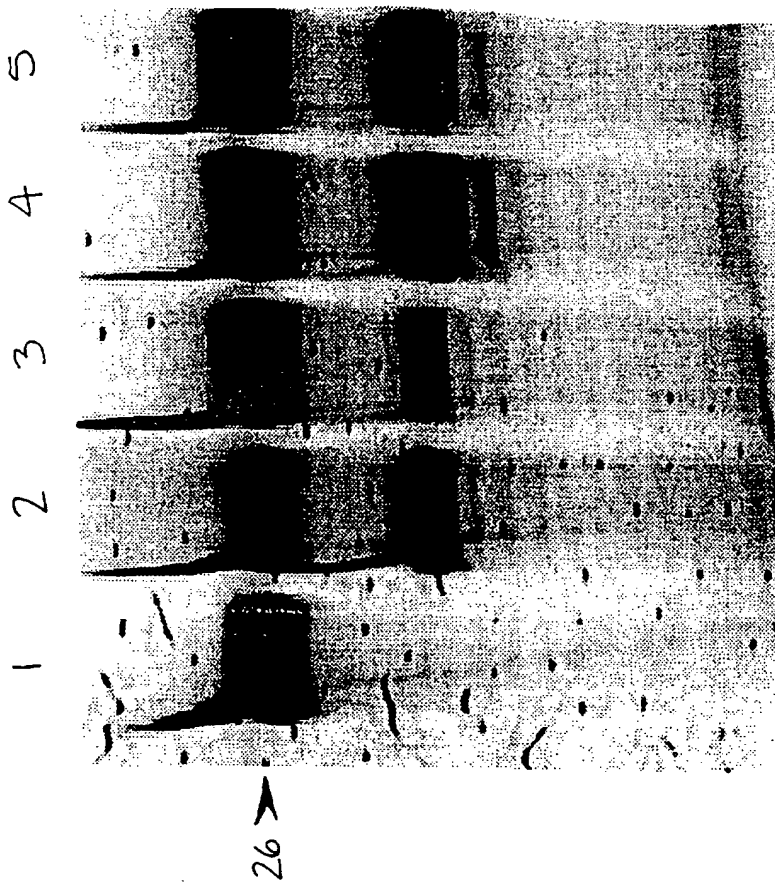
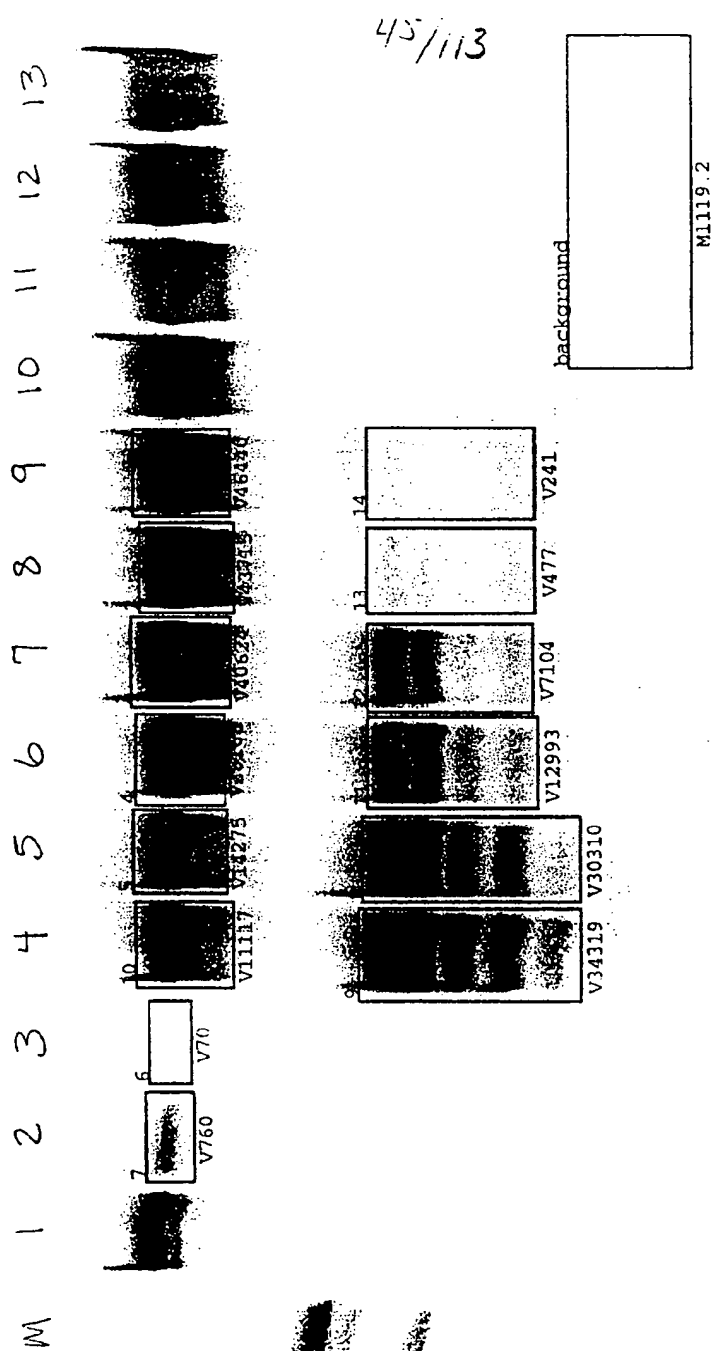
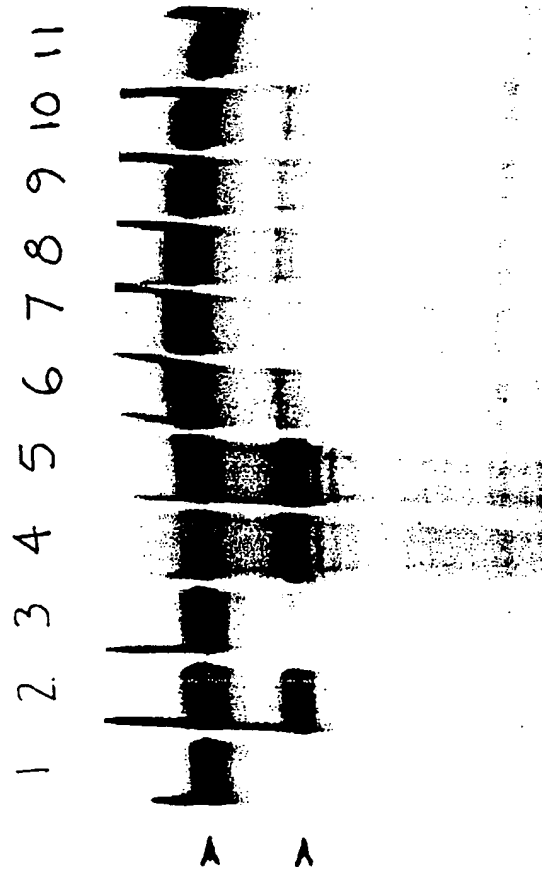


FIGURE 3a



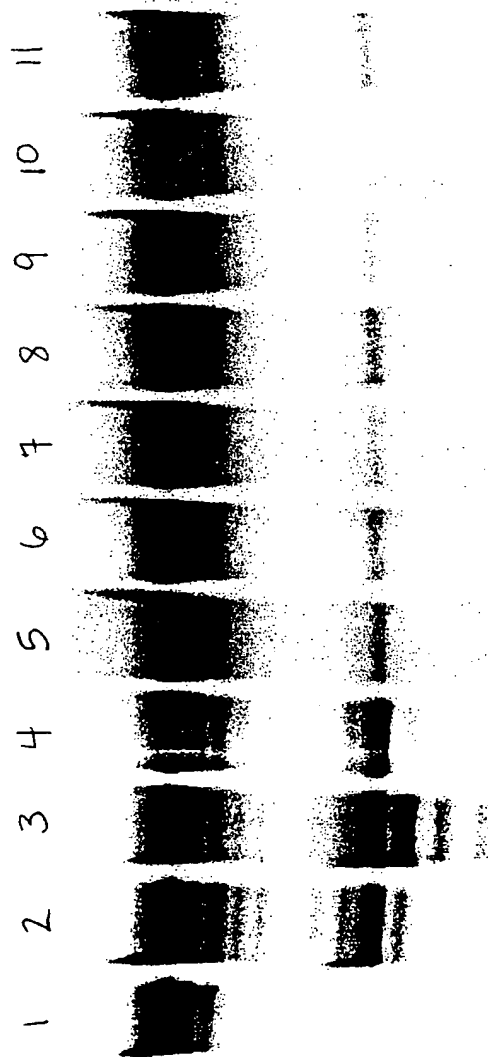
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FIGURE 33

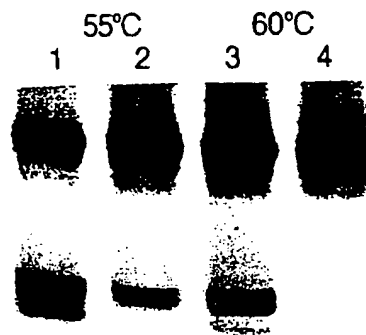


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FIGURE 34

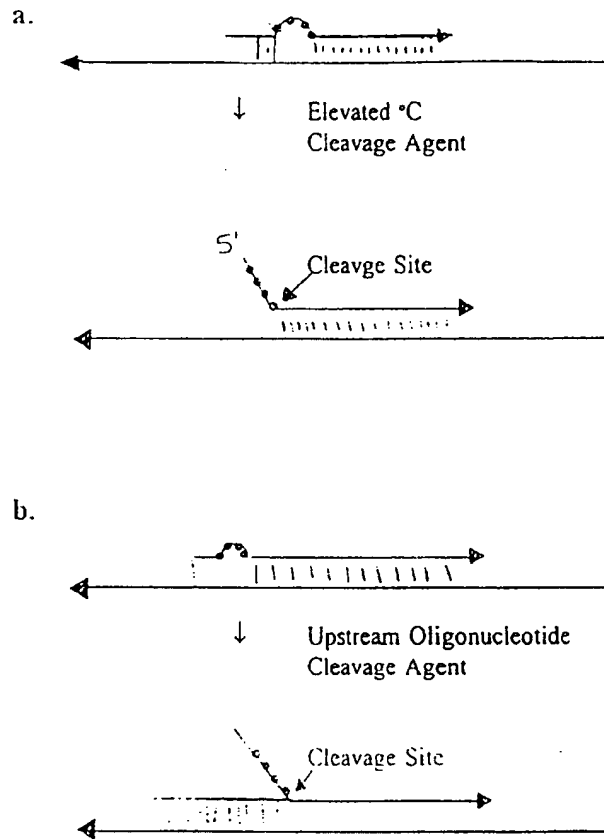


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FIGURE 35



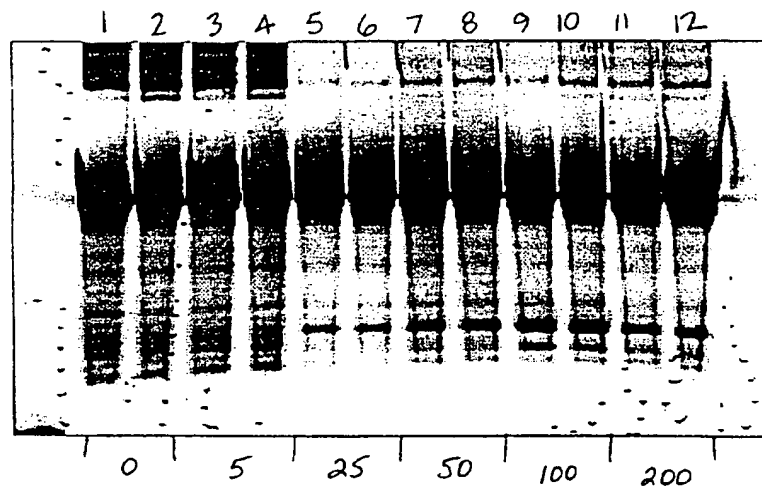
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FIGURE 36



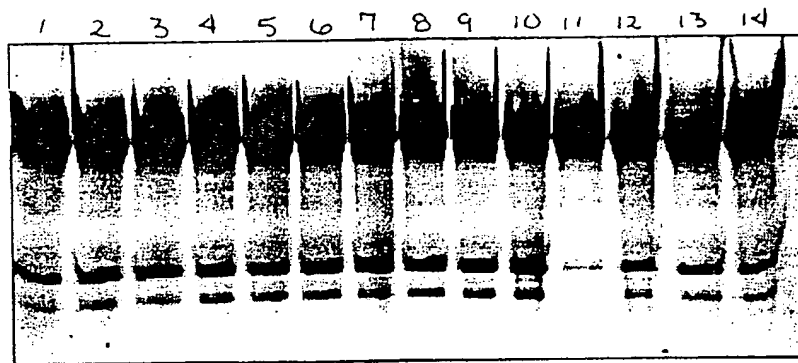
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FIG. 38



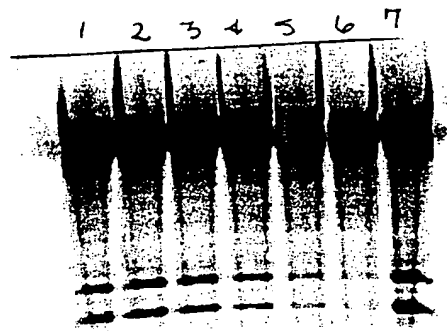
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FIG. 39



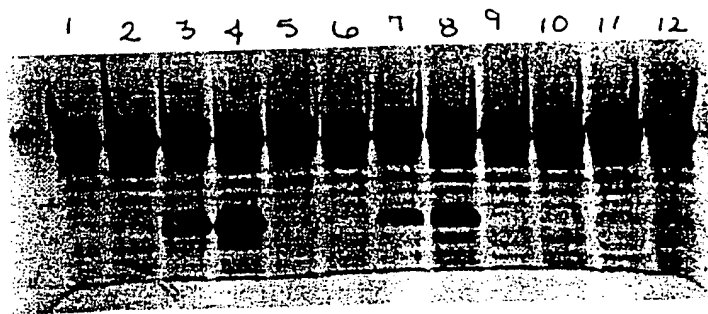
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FIG. 40



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FIG. 41



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FIG. 42B

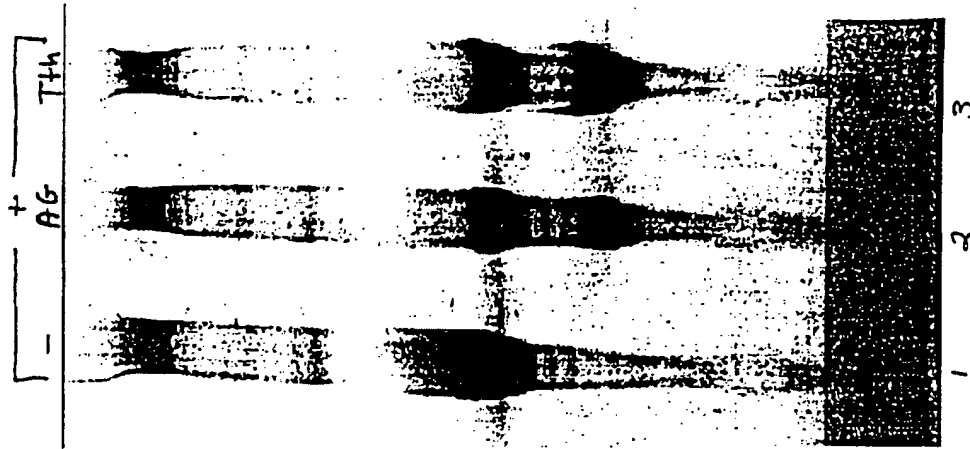
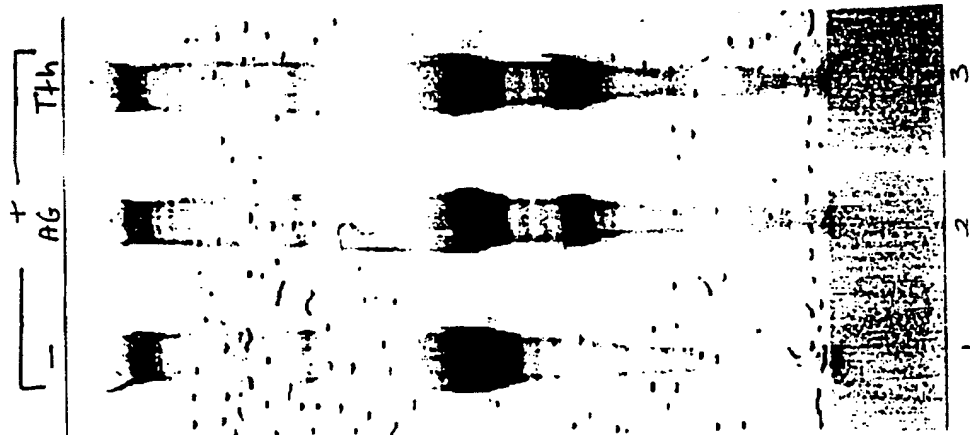


FIG. 42A



target RNA

uncleaved
probe

cleaved
probe

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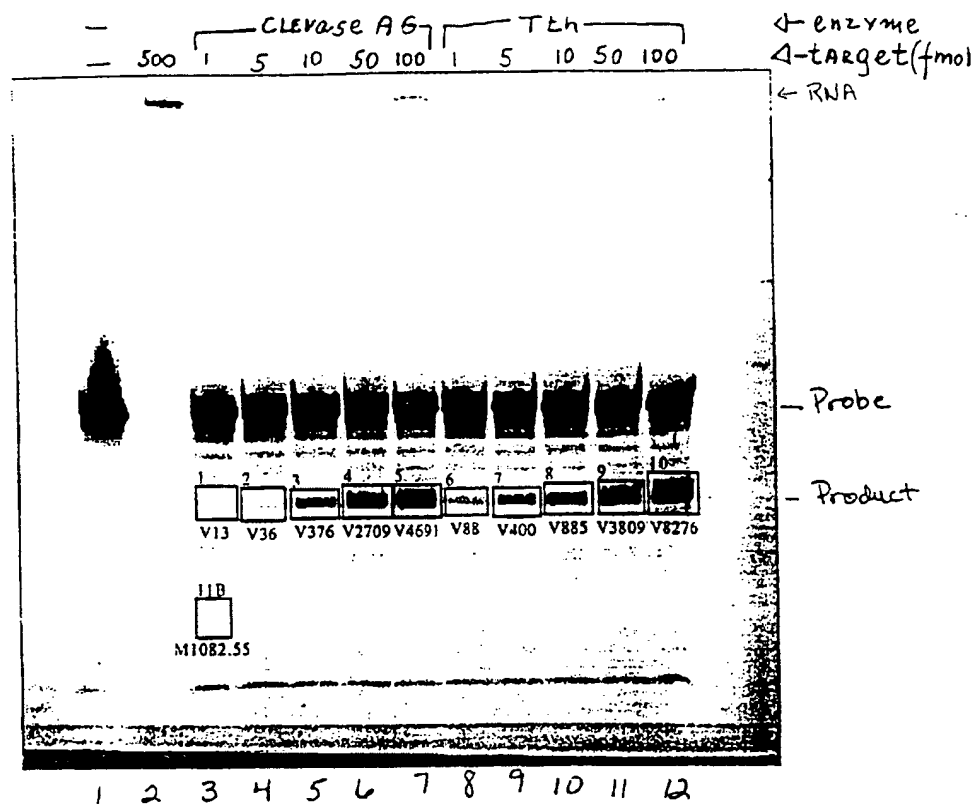


FIG. 43

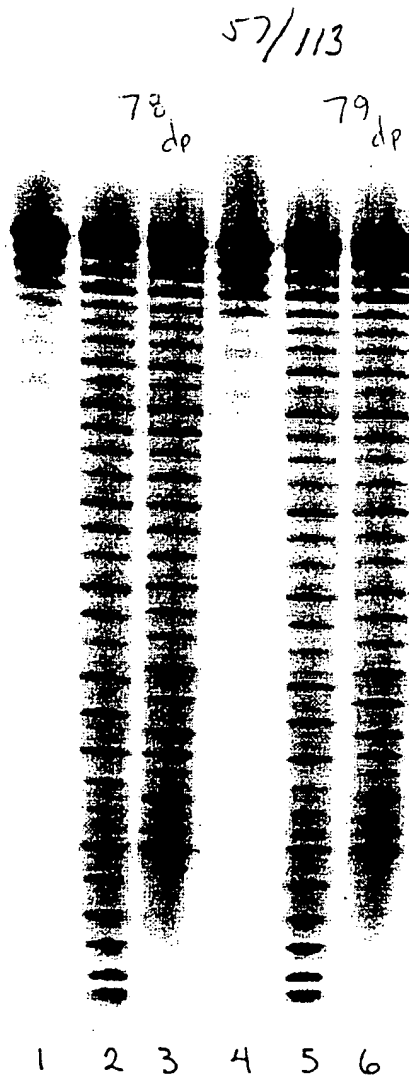
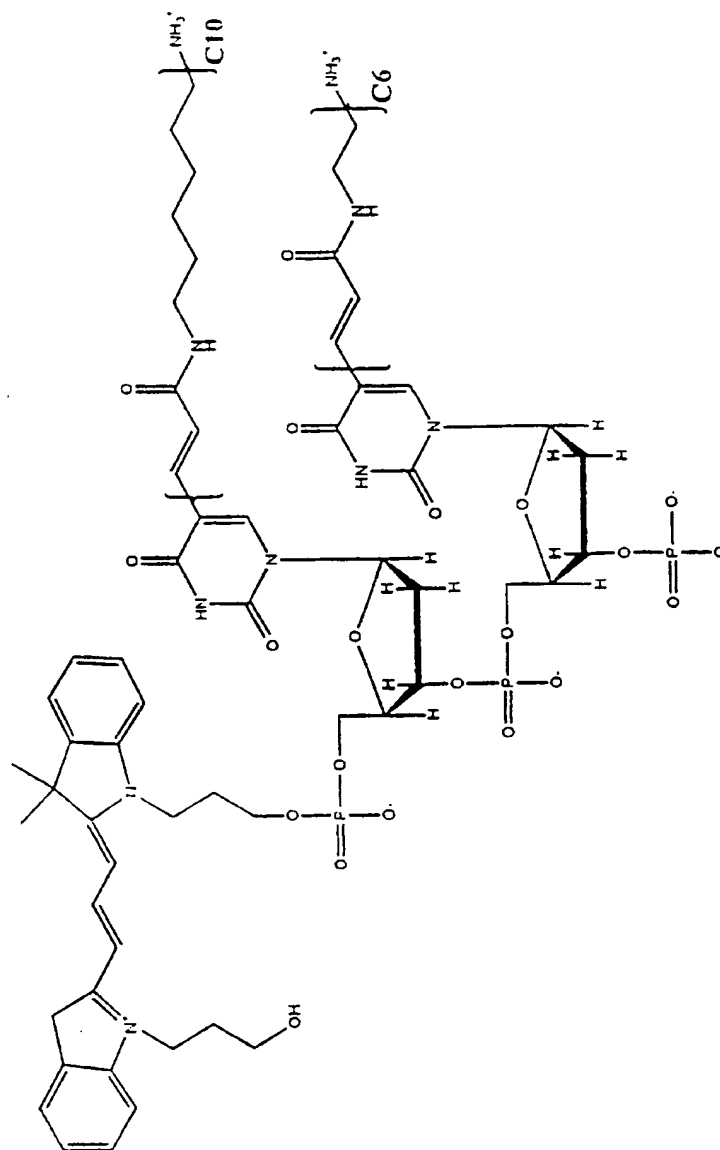


FIG. 44

FIGURE 45

70 (C10 amino T's)

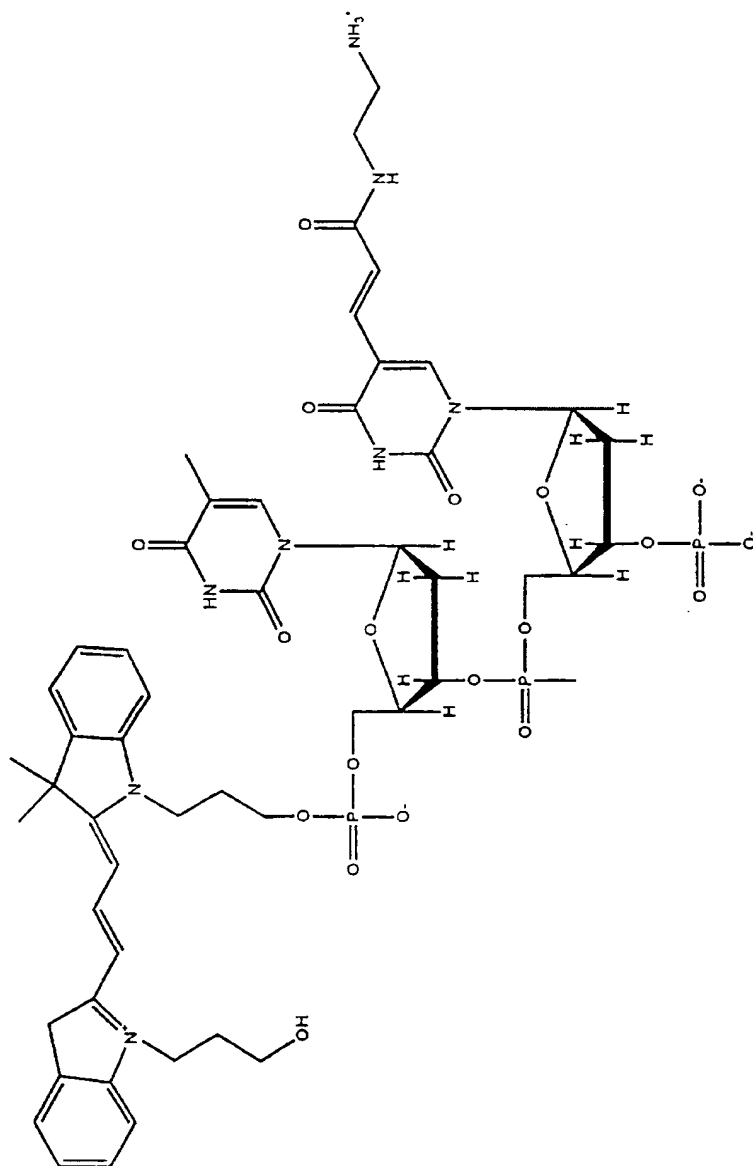
74 (C6 amino T's)



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FIGURE 4c

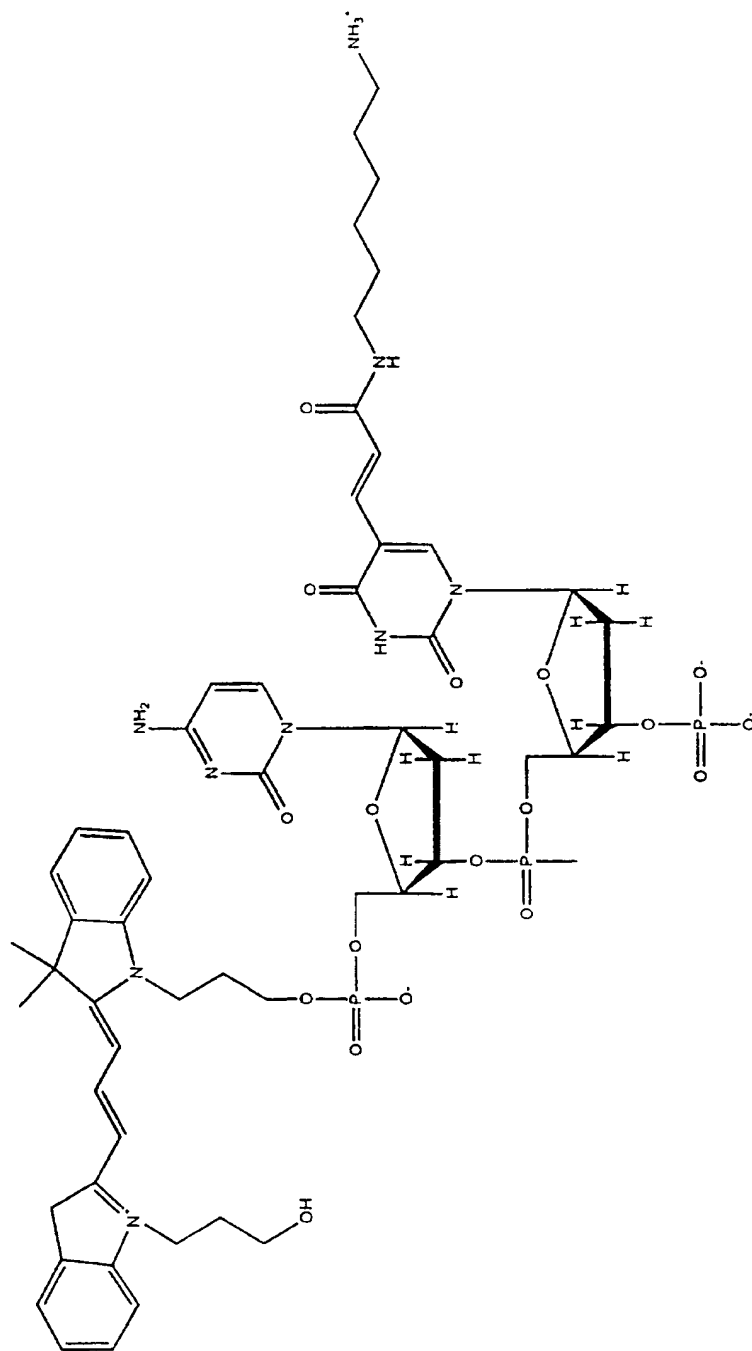
75



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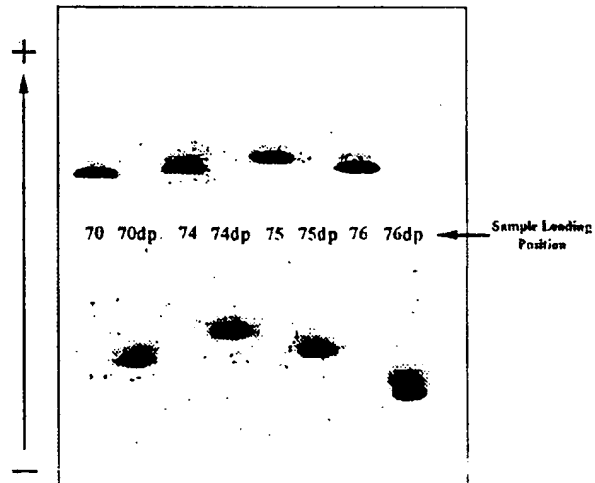
FIGURE 47

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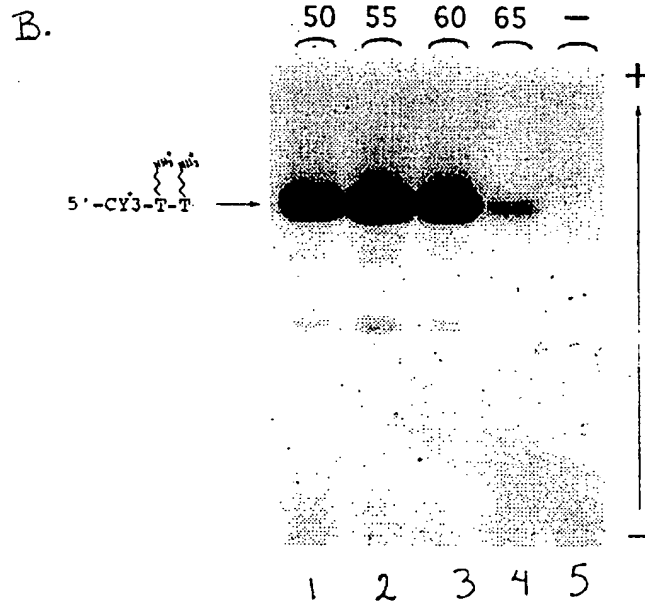
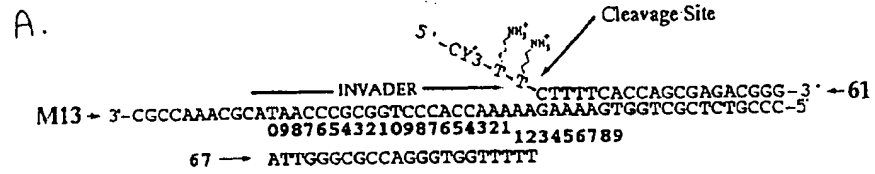


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FIGURE 48

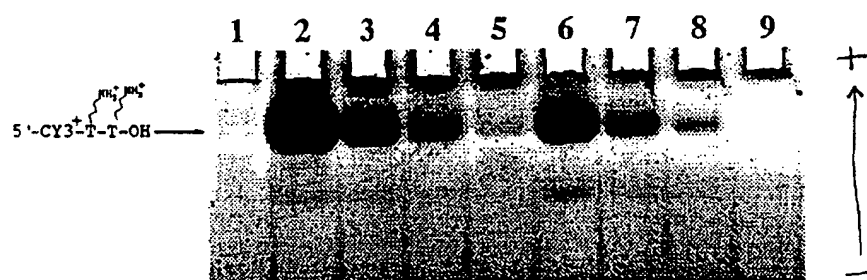


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FIGURE 49



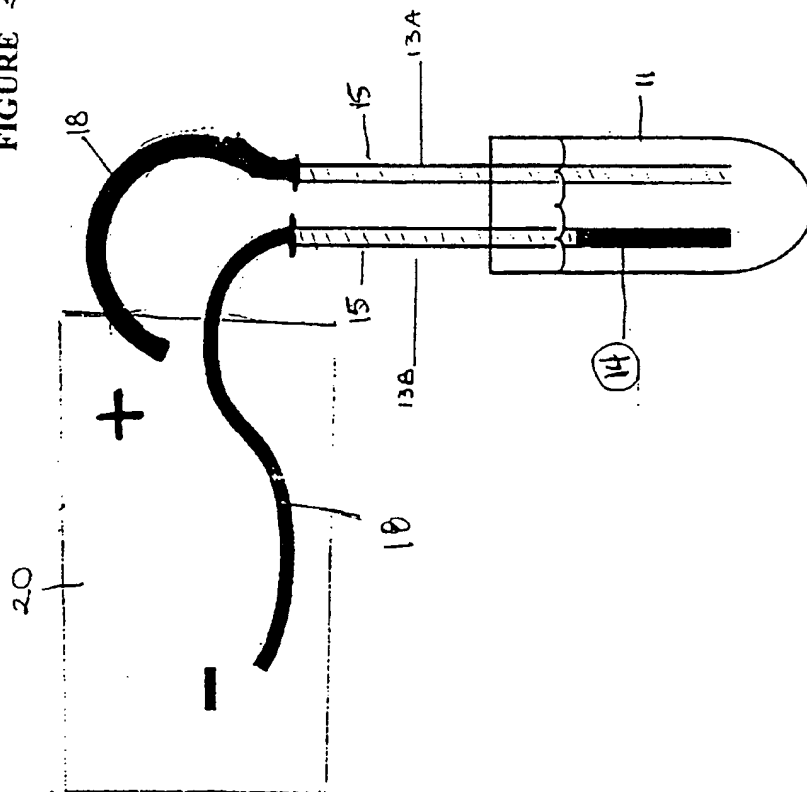
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FIGURE 50



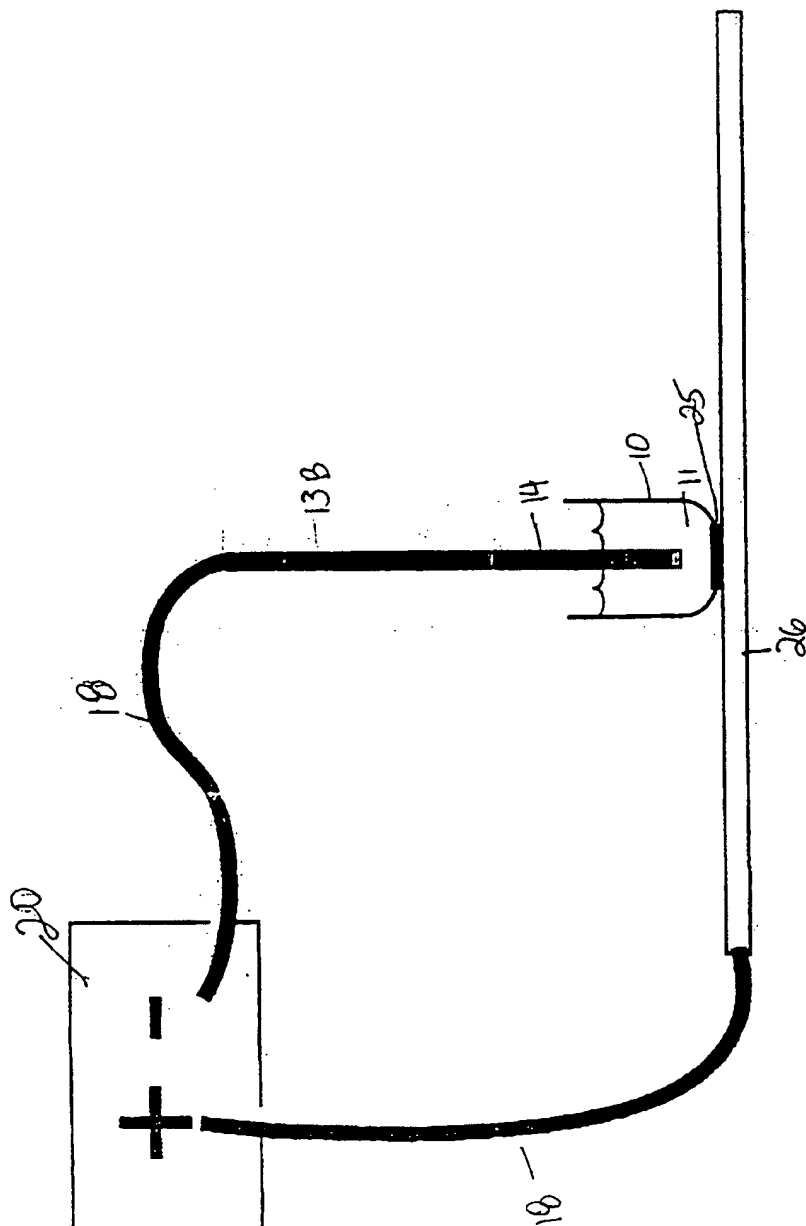
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FIGURE 5/



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FIGURE 53



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FIGURE 53

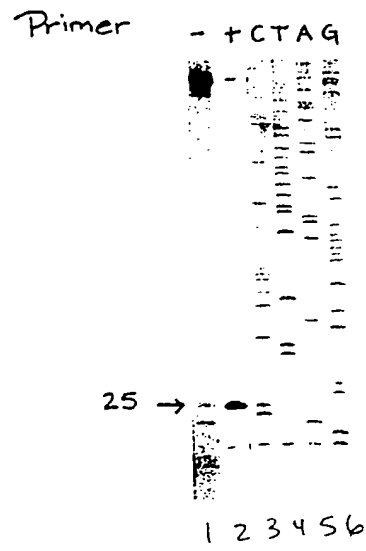
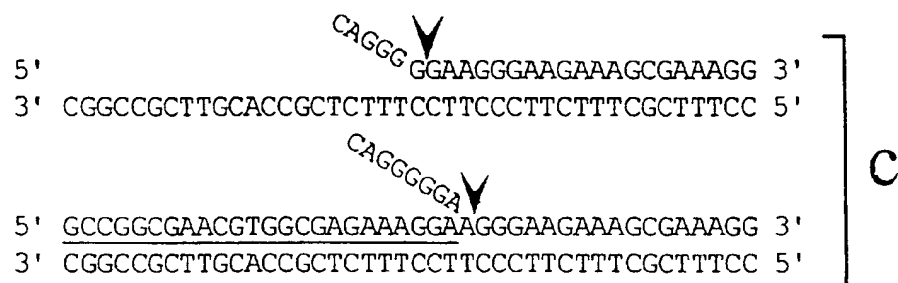
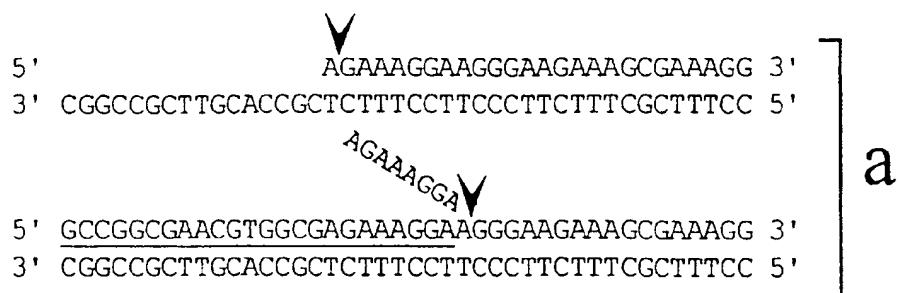
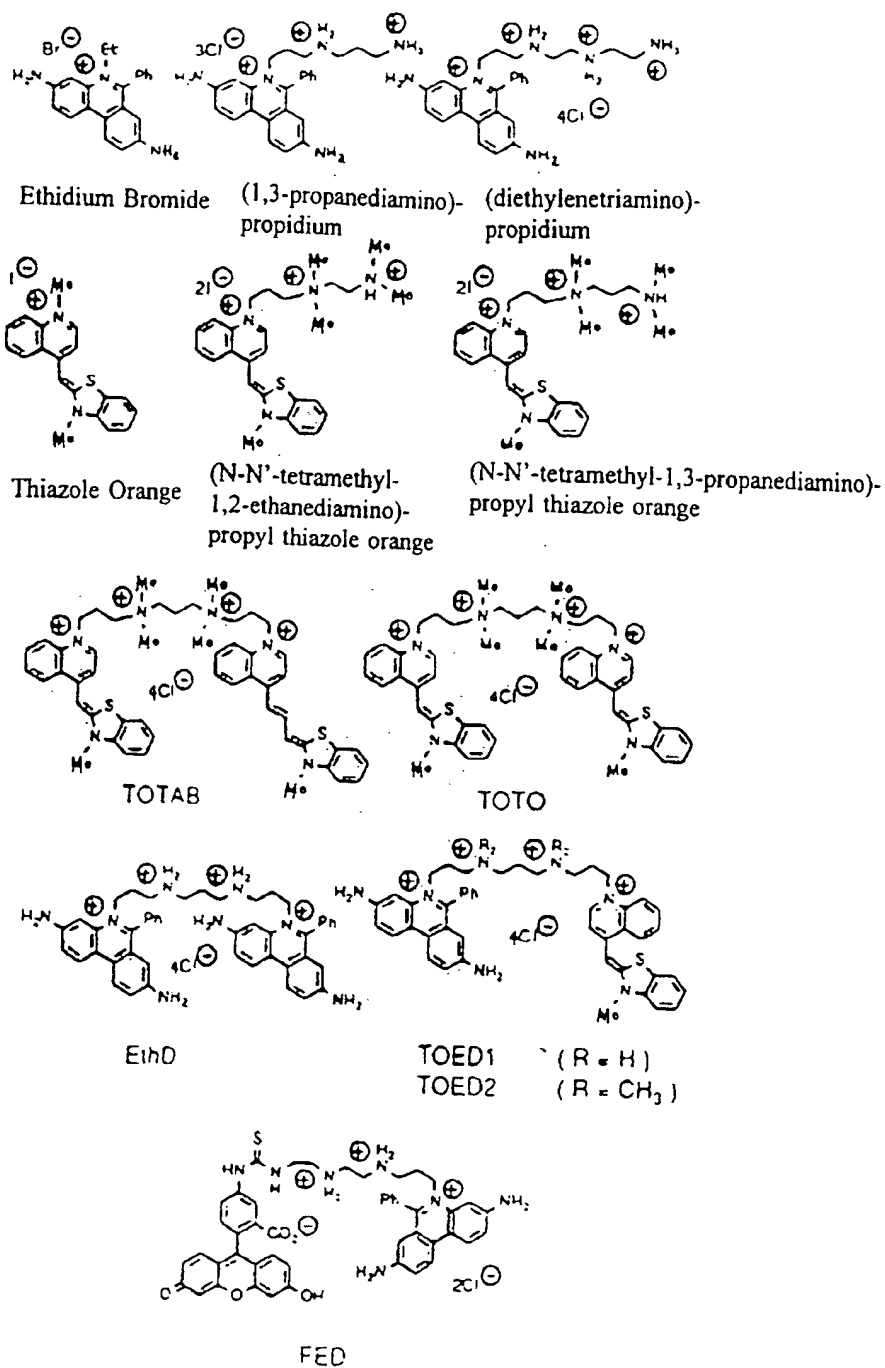


FIGURE 54 67/113



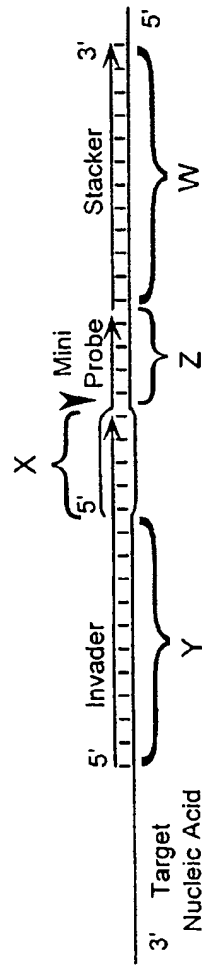
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FIGURE 55



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FIG. 57



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FIG. 58

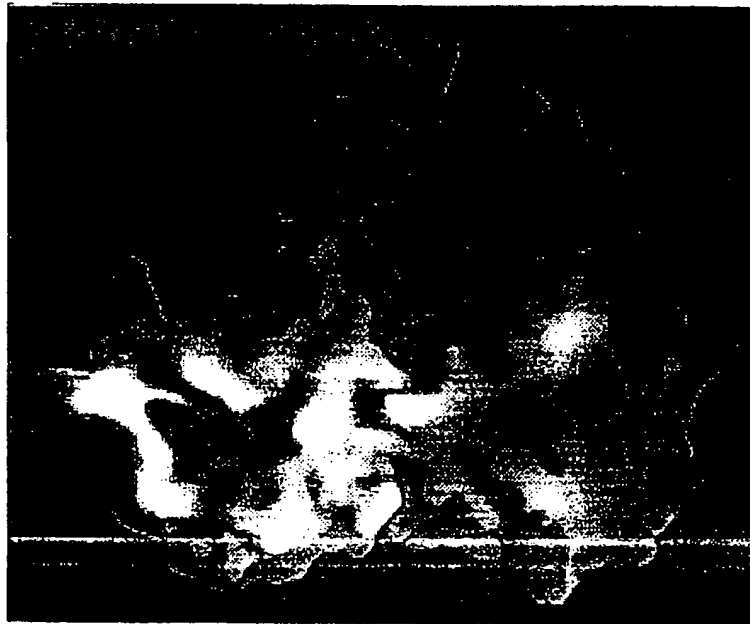


FIGURE 598

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	150	160	170	180	190	200	210	
120	MTENCKYLLSLMGIPYVEAPSEGEAOASYNIAKKGDVWVVSODYDALLYGAPRVVRNLTTTKEM----	MJAFEN1.PRO						
121	QLTEDAKKLELMGIPYVQAPSEGEAOAAYNIAAKGSVYASASODYDSLLFGAPRLVRNLITGKRKLPGK	PFUFEN1.PRO						
122	WHDECKHLLSLMGIPYLDAPSEAEASCAALVKAGKVYAAATEMDCLTFGSPVLMRHLTASEAKKLPIQ	HUMFEN1.PRO						
123	WHDECKHLLSLMGIPYLDAPSEAEASCAALAKAGKVYAAATEMDCLTFGSPVLMRHLTASEAKKLPIQ	MUSFEN1.PRO						
124	WHDECKHLLSLMGIPYIAPTAEAOCAELAKAGKVYAAASEMDTLCYRTPFLLRHLTFSEAKKEPIH	YST510.PRO						
125	YIKEYVOELLSRFGIPYITAPMEAEAOCAELLOLNLVGGITDDSDVFLFGGTKYKNMFHEKNY----	YSTRAD2.PRO						
126	MIKECOELLRLFLGPIYVAPOEAEAOCSKILELKLVDGIVTDDSDVFLFGGTRVYRNMFNKNF----	SPORAD13.PRO						
127	MFLESQELLRLFGIPYIOAPMEAEAOCAILDLTQOTSGTITDDSDIWLFGARHVVYRNFNKNF----	HUMXPG.PRO						
128	MFLESQELLRLFGVPYIOAPMEAEAOCAVLDLSQOTSGTITDDSDIWLFGARHVVYKNFFNKNF----	MUSXPG.PRO						
129	MFLESQELLRLFGIPYIVAPMEAEAOCAILDLTQOTSGTITDDSDIWLFGARHVVYKNFFSONKH----	XENXPG.PRO						
130	MYETNALITELGIKVIAPGDGEAOCCARIEDLGVTSGCITDIFYFLFGGKNLVRFDFTAGT-----	CELRAD2.PRO						

	220	230	240	250	260	270	280	
131	-----PELIELNEVLEDLRISLDDLIDIAIFMGTDYNPGGV--K--GIGFKRAYELVRSGVAK--DV	MJAFEN1.PRO						
132	-----KPELILEEVVKELKTREKLIELAILVGTDYNPGGI--K--GIGLKKALEIVRHSKDLAKF	PFUFEN1.PRO						
133	-----KSKILGELGLNOEQVDLCILLGSDYCESIRGIGPKRAVDLIQK--HKSIEEIVRRLDPN-----KY	HUMFEN1.PRO						
134	-----KSRVLGELGLNOEQVDLCILLGSDYCESIRGIGAKRAVDLIQK--HKSIEEIVRRLDPS-----KY	MUSFEN1.PRO						
135	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVTALKIKT--HGSIEKIVEFIESGESNNTKW	YST510.PRO						
136	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	YSTRAD2.PRO						
137	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	SPORAD13.PRO						
138	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	HUMXPG.PRO						
139	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	MUSXPG.PRO						
140	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	XENXPG.PRO						
141	-----KPELILROLDLTIEOFVDLCIMLGCDYCTSIIRGVGPVSSIEVIAEF--GNLKNFKDWNNGOFDKRK	CELRAD2.PRO						

FIGURE 59c

	290	300	310	320	330	340	350	
1	PEVYDEIKRIFKEPKV	---	---	---	TD--	NYSLSLKLPOKEGIIKFLVDENDFN	YD	MJAFENI.PRO
2	SDVDLYAIKEFFLNPPV	---	---	---	ID--	NYNLVWRDPDEEGILKFLCDEHDFSEE		PFUFENI.PRO
3	ENMLHKEAHOLFLEPEV	---	---	---	LDPESELKWSPEPNEEELIKFMCGEKOFSEE			HUMFENI.PRO
4	ENMLHKEA00LFLEPEV	---	---	---	VDPESELKWSPEPNEEELVKFMCGEKOFSEE			MUSFENI.PRO
5	EDMPYKQARMFLDPEV	---	---	---	IDGNEINLKWSPPKKELIEYLCDDKKFSEE			YST510.PRO
6	ETENKFEKDLRKKLVNNE	ILDDDFPSVNV	DAYMRPEVDHDT	TPFVVGVPD	DLMLRSFMKTOLGWPHE			YSTRAD2.PRO
7	QVNTPYKKRINKLVGK	ILPSEFPNPL	VDEAYLHPAVDDSKOSFOWG	IPDLDELROFLMATVGWSKO				SPORAD13.PRO
8	EPHPDITKVKKKL	RTLOLTPGFPNP	PAVEAYLKPVVDDSKGSFLWGKPD	DKIREFCORYFGWNRT				HUMXPG.PRO
9	EPHPDITKVKKKL	RLLOLTPGFPNP	PAVADAYLRPVVDDSRGCSFLWGKPD	VDKIREFCORYFGWNRM				MUSXPG.PRO
10	EPHPDITKVKKKL	RLLOLTPGFPNP	PAVASAYLKPVVDESKSAFSGWRPD	LEQIREFCESRFGWYRL				XENXPG.PRO
11	---	EKKVSRPHL	ISTAILLGCDYFORGVONIGIVSVFD	ILGEFGDDGNEE	IDPHVILDRFASYVRE			CELRAD2.PRO
	360	370	380	390	400	410	420	
12	PKHVDKLYNLIA	---	---	---	---	---	---	MJAFENI.PRO
13	KNGLERLKKAI	---	---	---	---	---	---	PFUFENI.PRO
14	PSGVKRLSKSROGS	TOGRLODFFKVT	---	---	---	---	---	HUMFENI.PRO
15	PSGVKRLSKSROGS	TOGRLODFFKVT	---	---	---	---	---	MUSFENI.PRO
16	PSGISRLKKGLKSG	IOGRLDGFFOVV	---	---	---	---	---	YST510.PRO
17	DEILPLIRDVNKRKK	---	---	---	---	---	---	YSTRAD2.PRO
18	DEVLPLVIODMHKKOF	---	---	---	---	---	---	SPORAD13.PRO
19	DESLFPVLKOLDA00TOL	RIDSFRLA00EKEDAKR	KSORLNRAVTCMLRKEKEAAASE	IEAVSVAM				HUMXPG.PRO
20	DESLYPVLKHLNAHOTOL	RIDSFRLA00EKODAKL	IKSHRLSRVTCMLRKEREKAPEL	TKVTEAM				MUSXPG.PRO
21	DEYLLPVLKOLNA00TOL	RIDSFRLA00EHEAAG	---	LKSORLRAVTCMKRKERDVEAE	EAAVAM			XENXPG.PRO
22	DELRSEDORPKLRLRRKKYNF	VPVGFPCNDVAVHNAI	TMYLPPVSSSEIPK	IPR	---	---	---	ANFOOVAEIM
	360	370	380	390	400	410	420	

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FIGURE 59D

PRO	440	450	460	470	480	490
MJAFEN1	PRO					
PFUFEN1	PRO					
HUMFEN1	PRO					
MUSFEN1	PRO					
YST510	PRO					
YSTRAD2	PRO					
SPORAD13	PRO					
HUMXPG	PRO					
MUSXPG	PRO					
XENXPG	PRO					
CEL RAD2	PRO					

FIGURE 57E

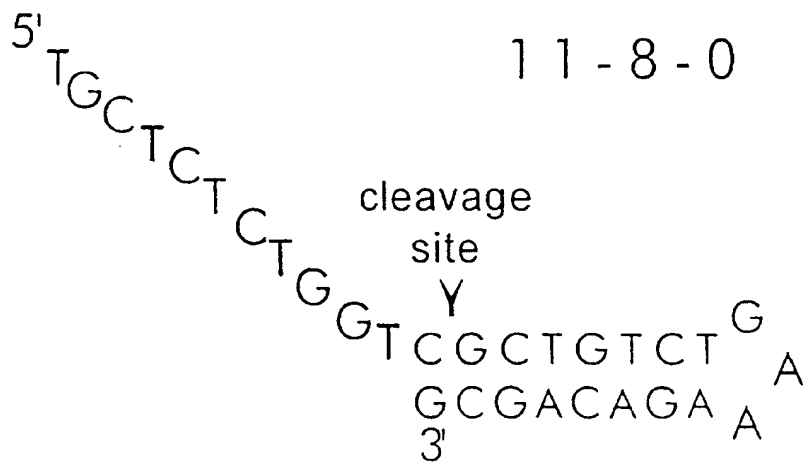
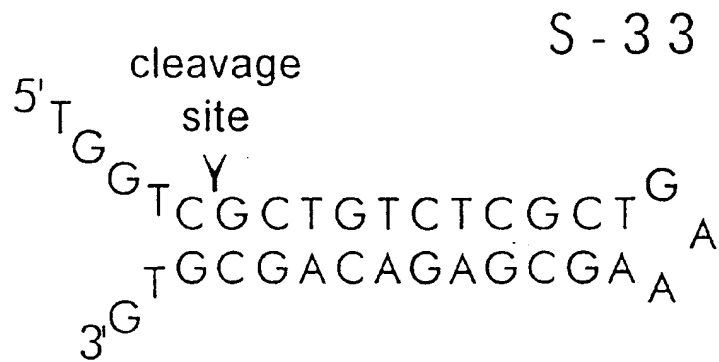
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MJAFEN1.PRO
PFUFEN1.PRO
HUMFEN1.PRO
MUSFEN1.PRO
YST510.PRO
YSTRAD2.PRO
SPORAD13.PRO
HUMXPG.PRO
MUSXPG.PRO
XENXPG.PRO
CELRAD2.PRO

122 MFKZ
125 MFKR
126 MARGK
127 MPRGK
128 MKGRR
129 MK-RKN
130 MRRRK
131 MKTZ
132 MKKT
133 MKRK
134 MKSD

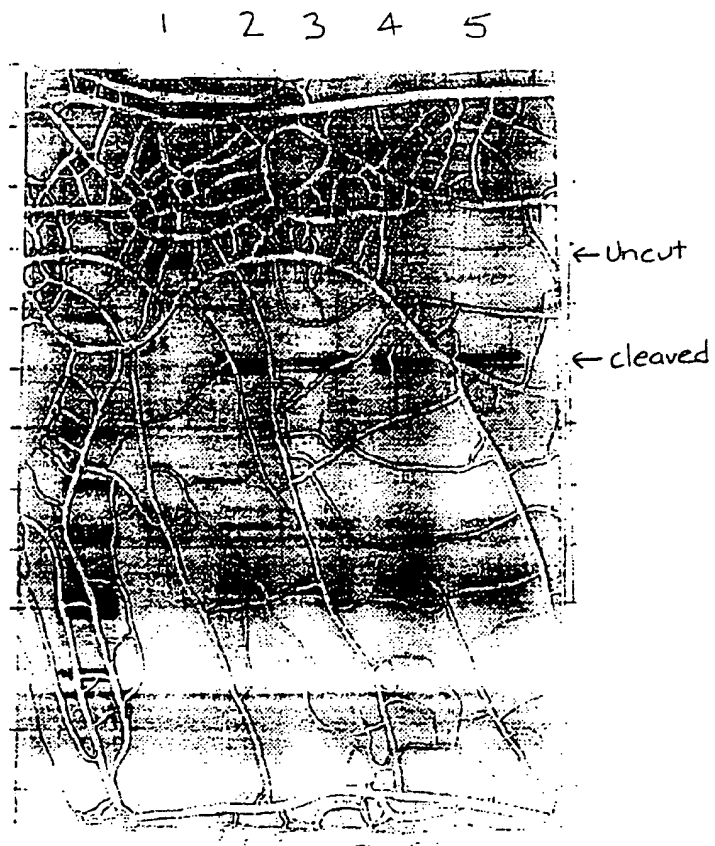
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FIGURE 60



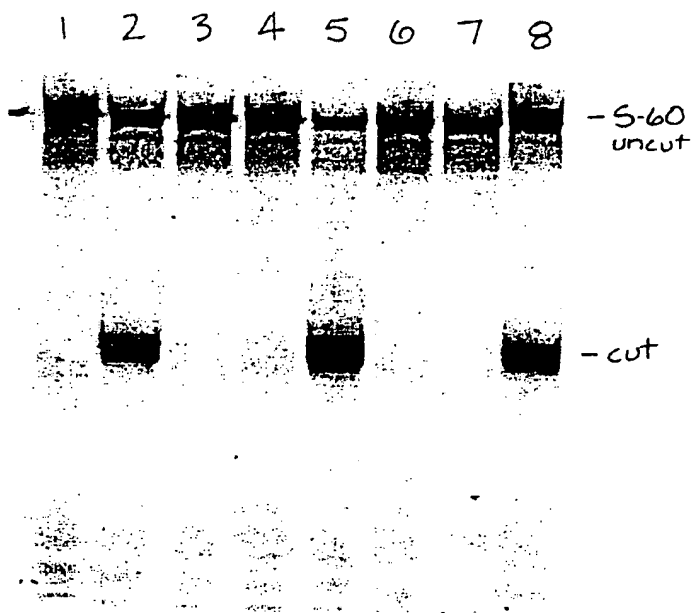
78/113

FIGURE 61



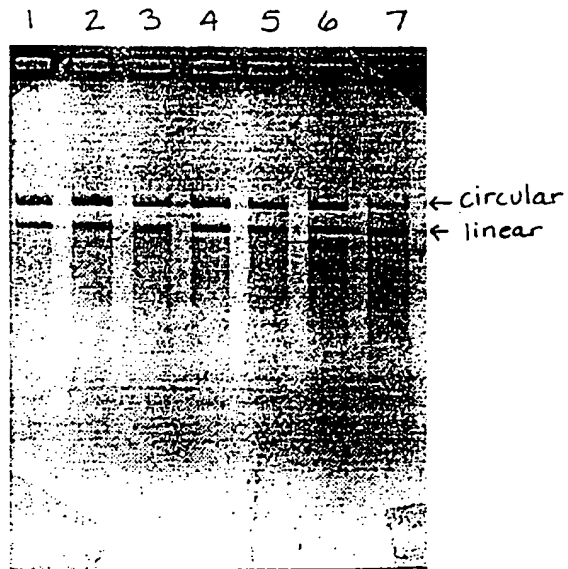
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FIGURE 62



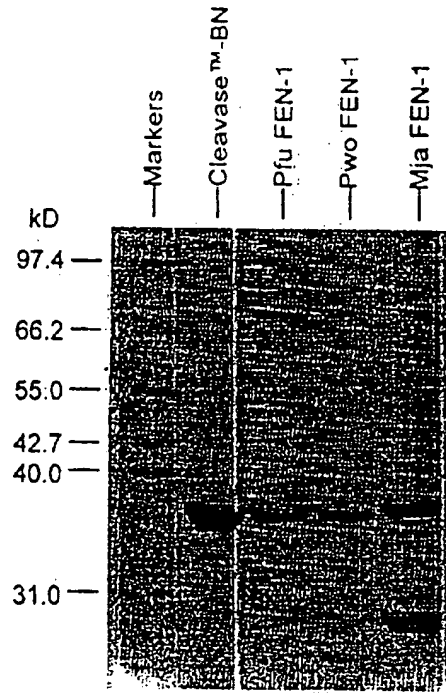
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FIGURE 63



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FIGURE 64



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FIGURE 65

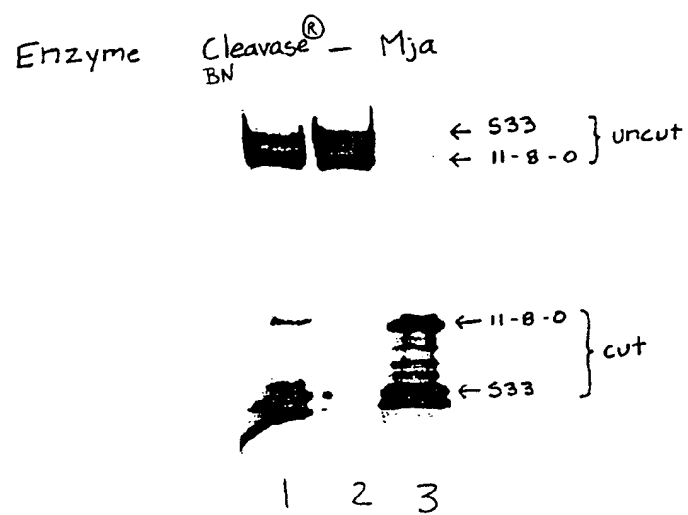
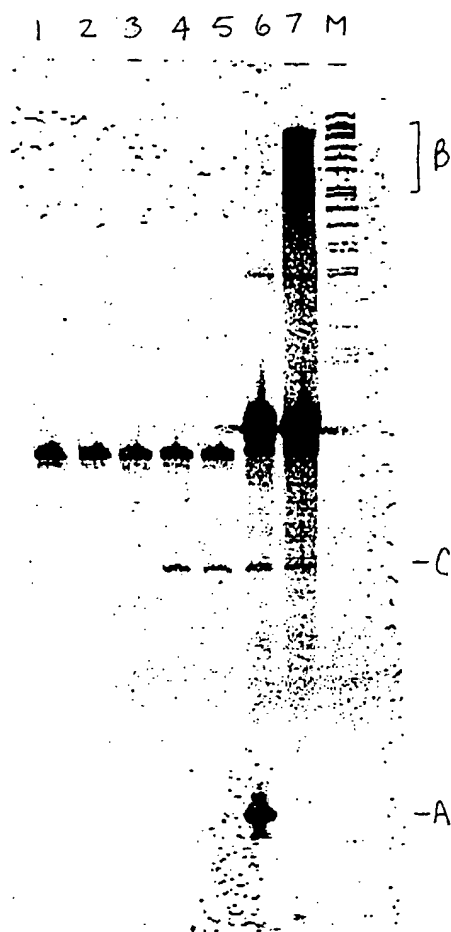


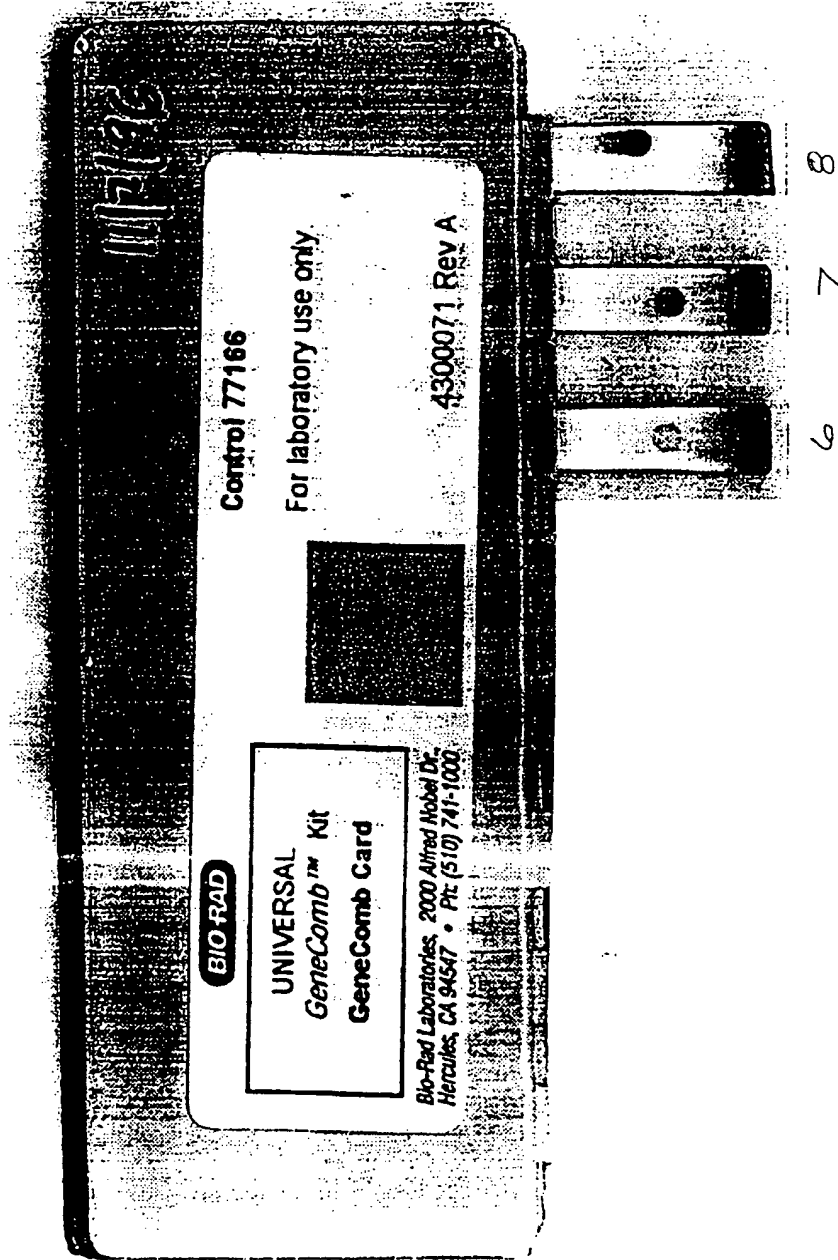
FIGURE 67

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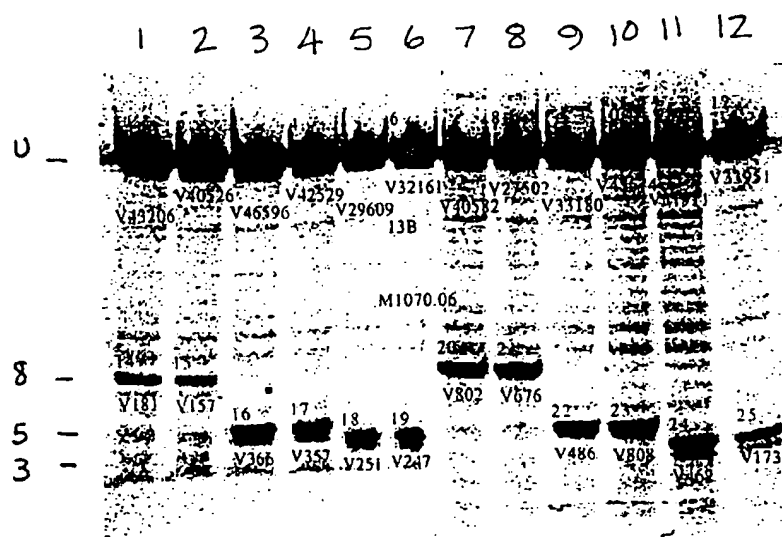
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FIGURE 68

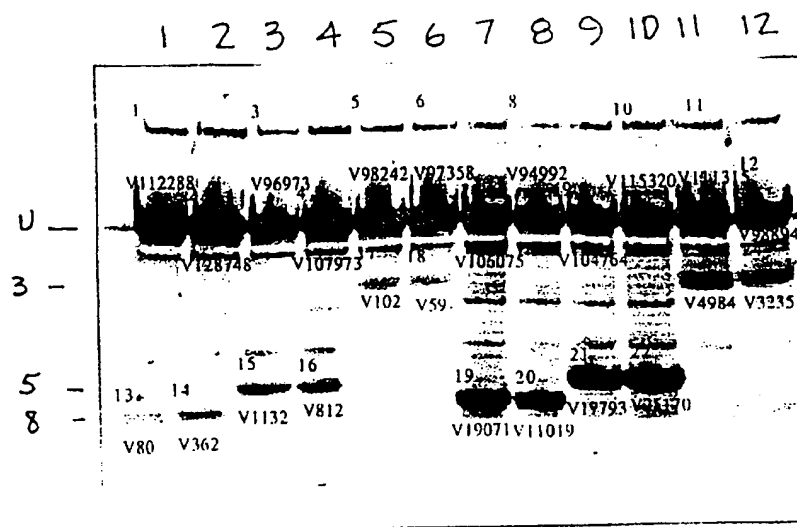


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FIGURE 69

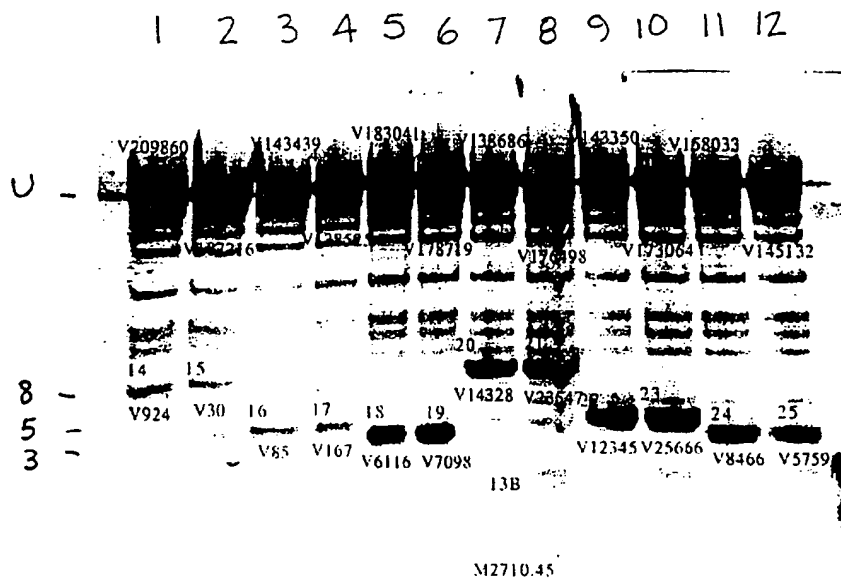


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FIGURE 70



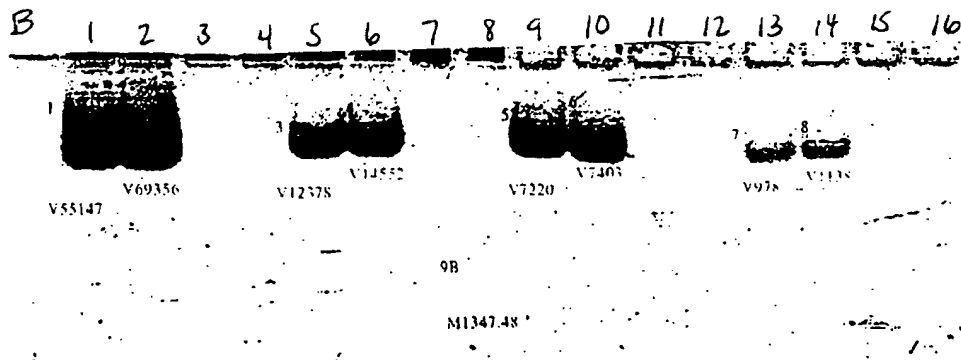
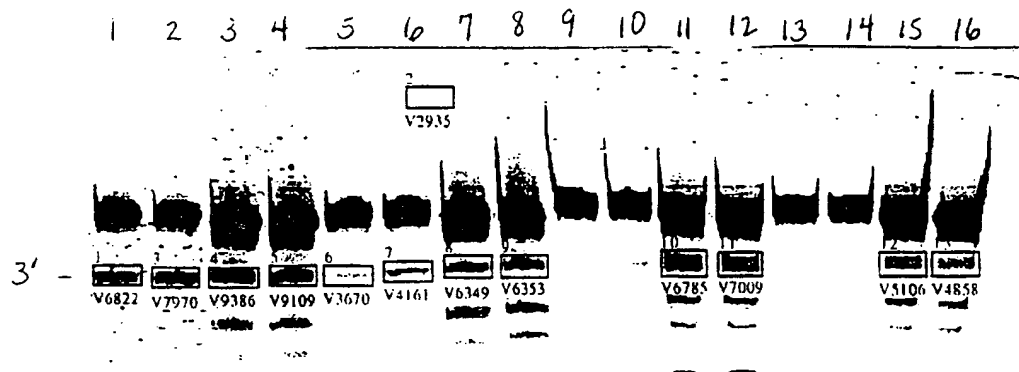
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FIGURE 71

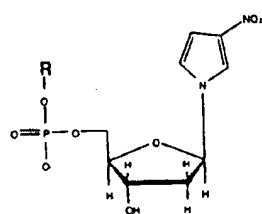


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FIGURE 72

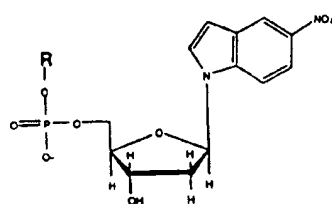
A



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FIGURE 73



3-nitropyrrole



5-nitroindole

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FIGURE 74

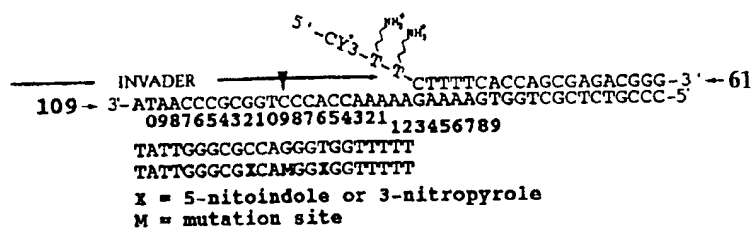


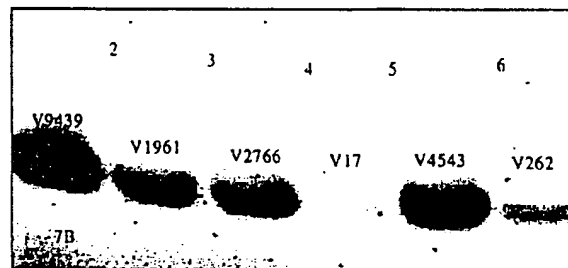
FIGURE 75

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	All comp	1 Base Mismatch	All comp 2 NI	1 Base Mismatch 2 NI	All comp 1 NP	1 Base Mismatch 1 NP
Insert #	67	114	115	116	112	113

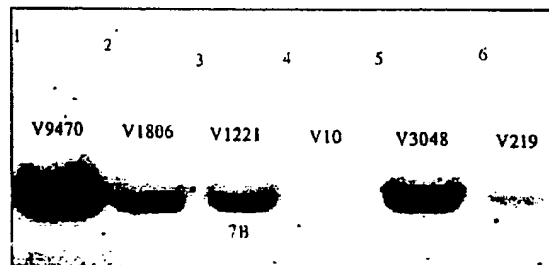
A

52°C



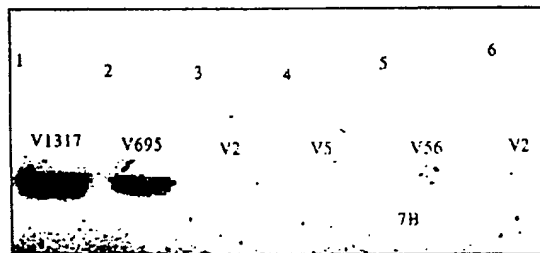
B

55°C



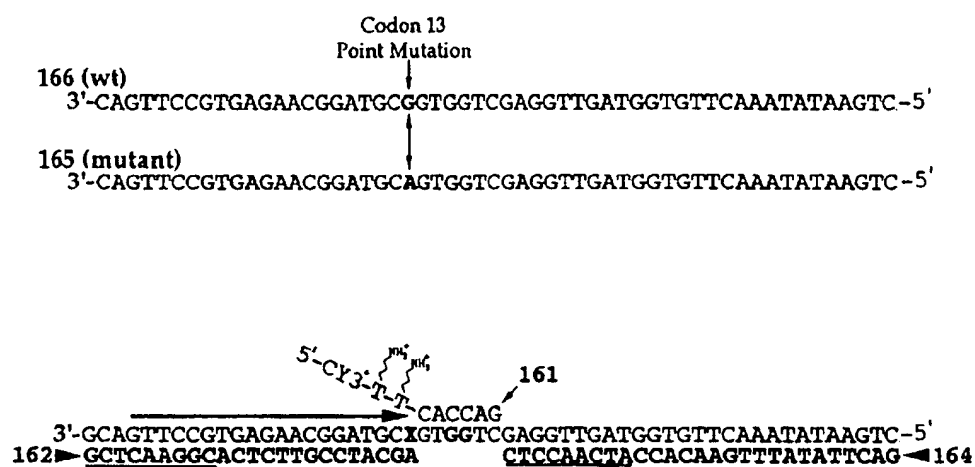
C

58°C



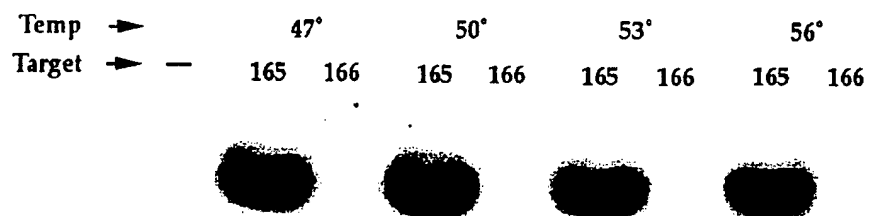
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FIGURE 76



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FIGURE 77



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FIGURE 7B

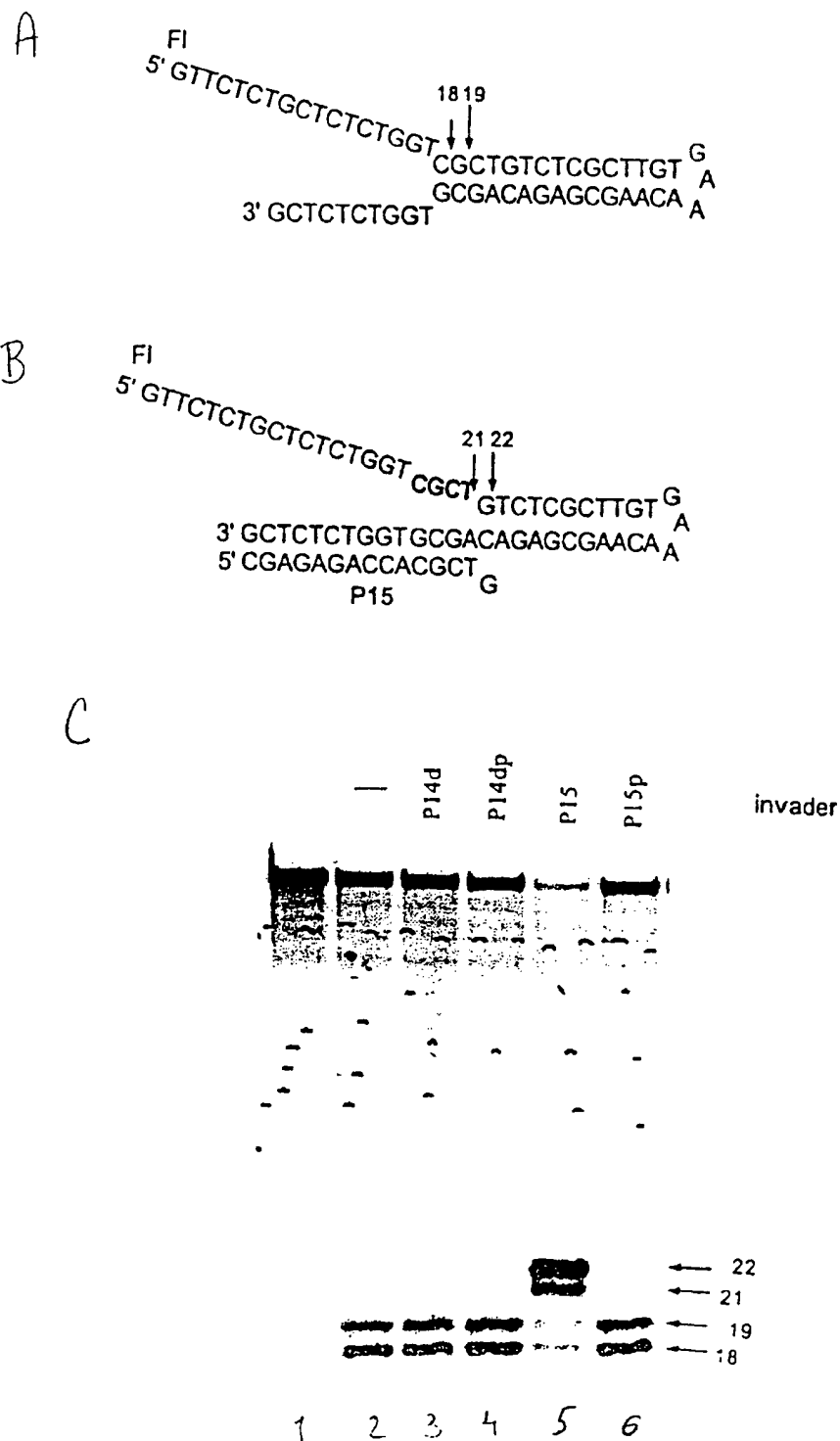


FIGURE 79 96/113

Invader 3'-end Substituents

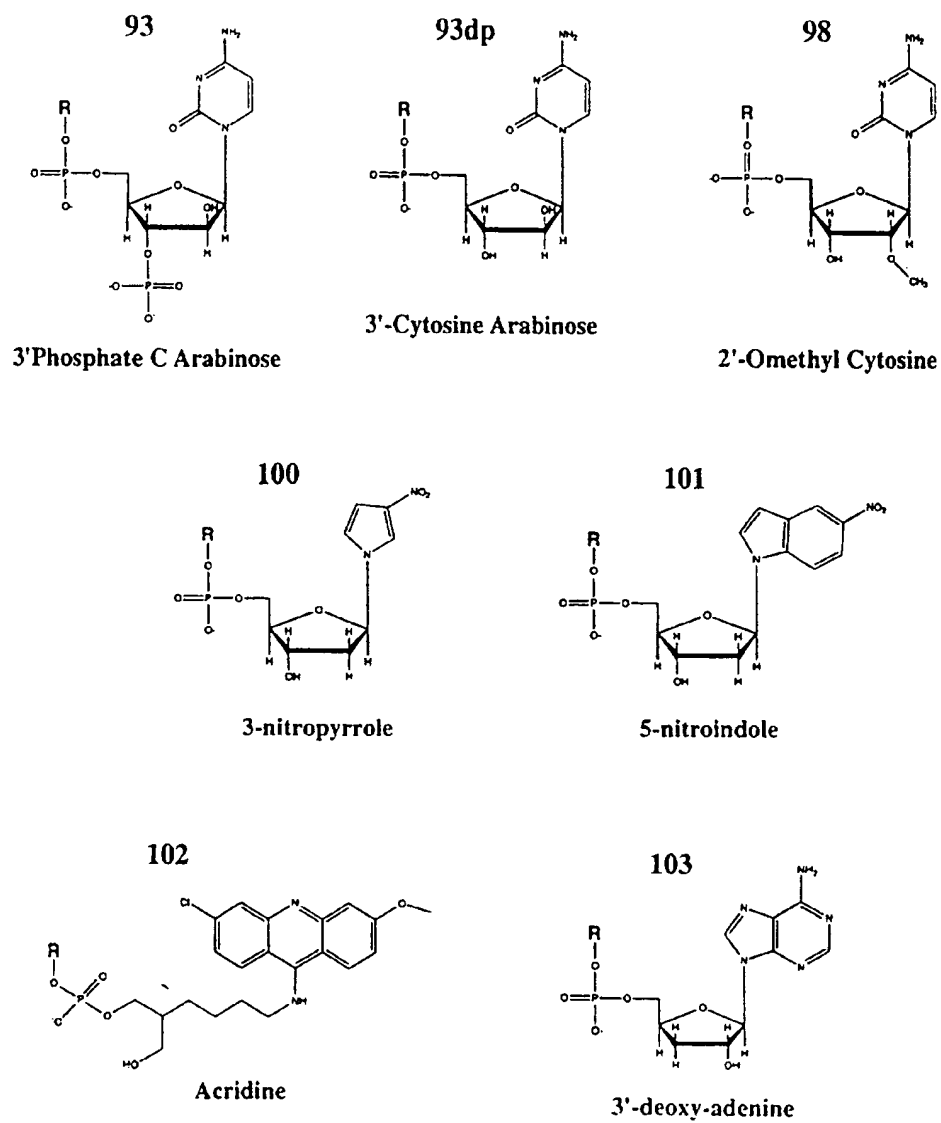
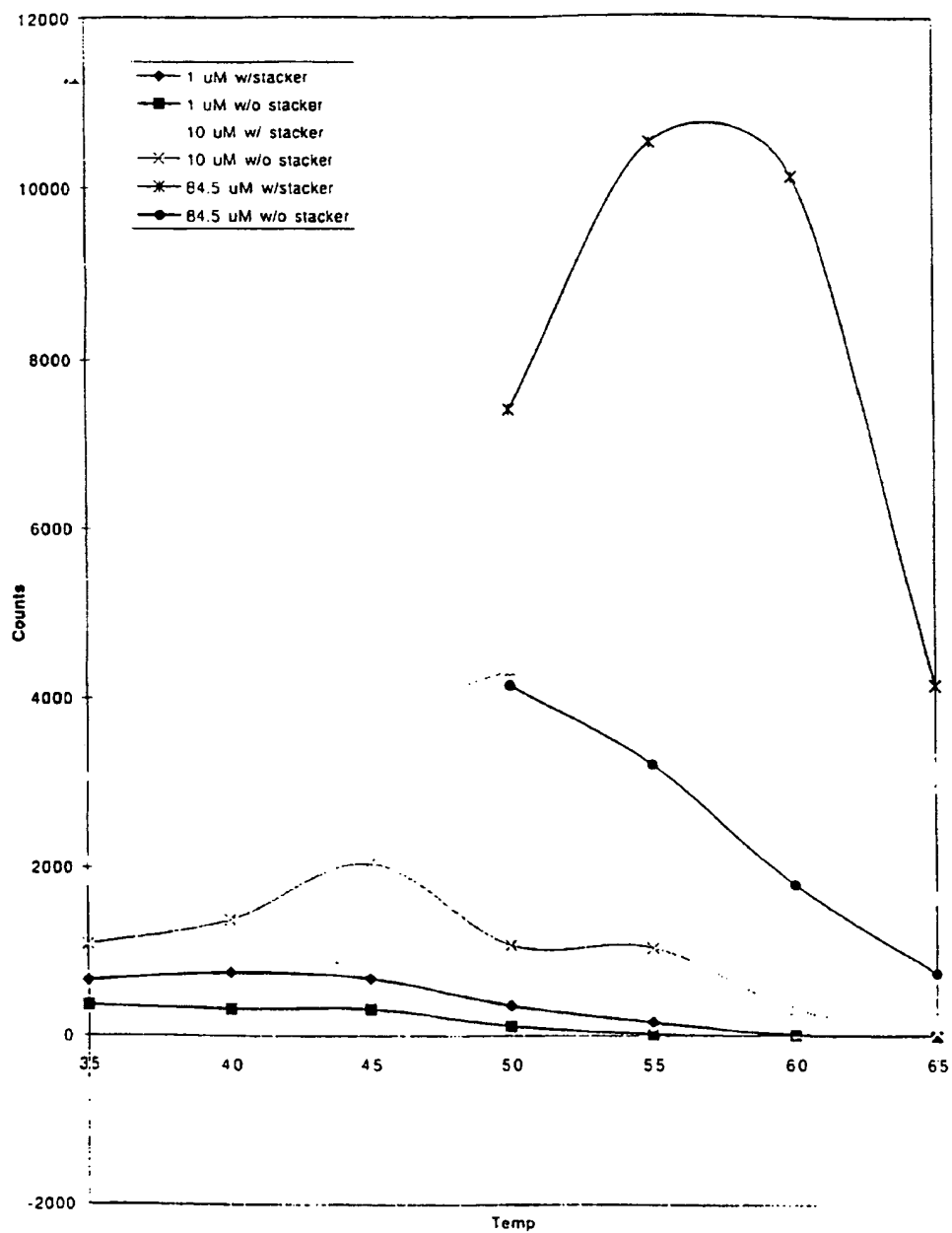


FIGURE 80

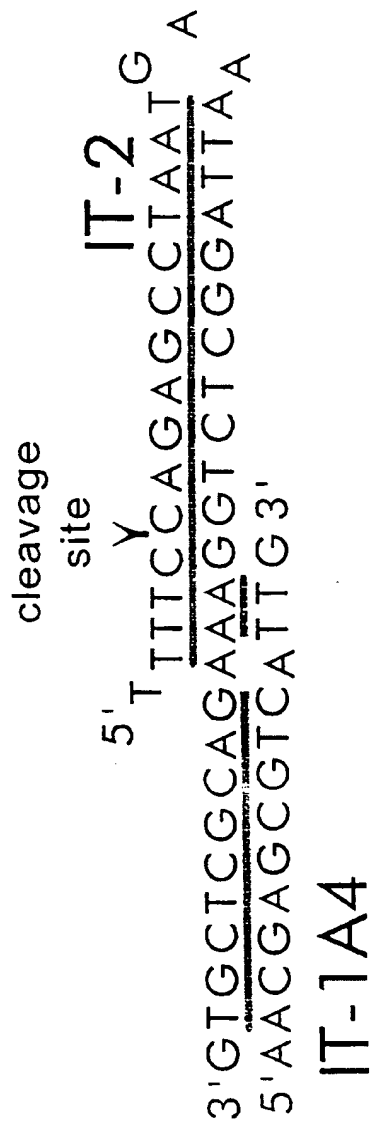
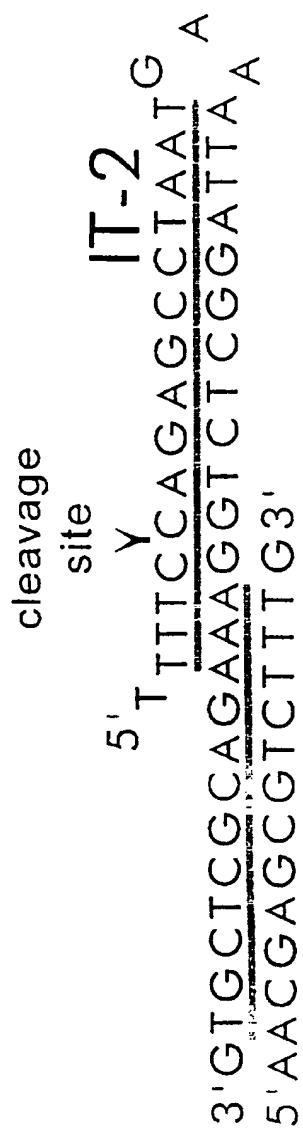
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Concentration of Probe w/ and w/o Stacker vs Temp



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FIGURE 8/



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FIGURE 82

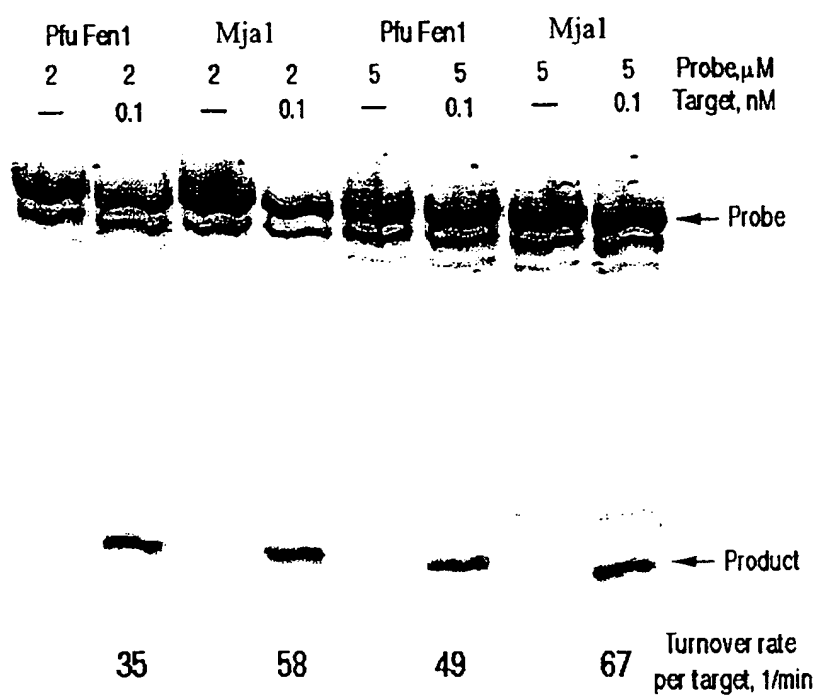
1 2 3 4

!  -uncut

—

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FIGURE 83



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FIGURE 84

1 2 3 4 5

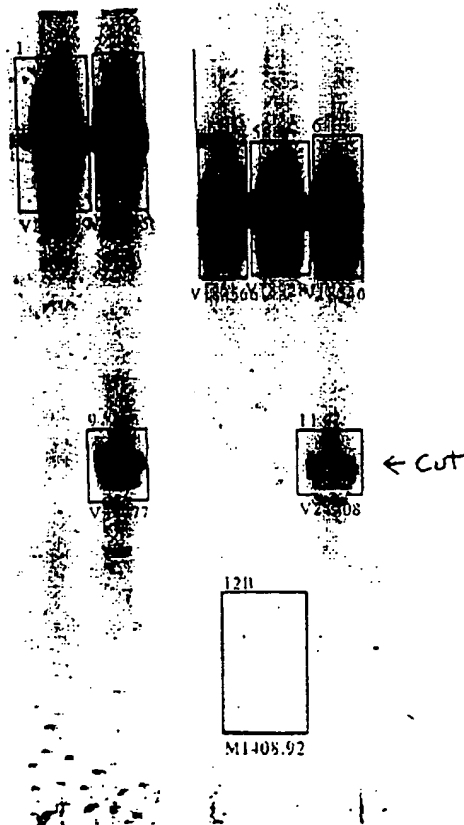
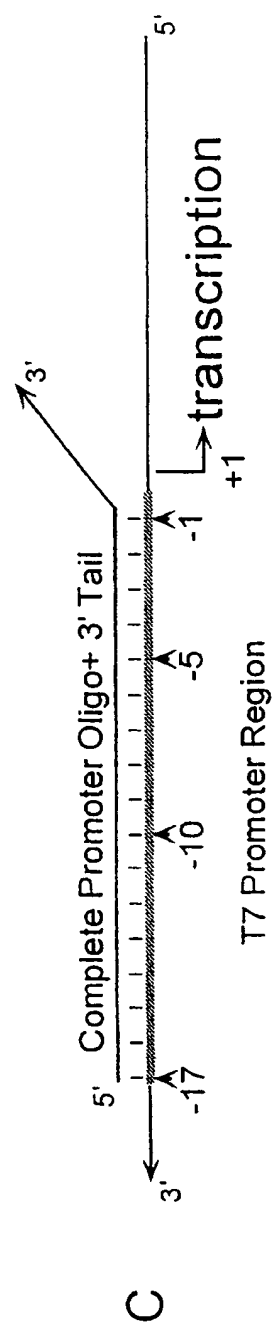
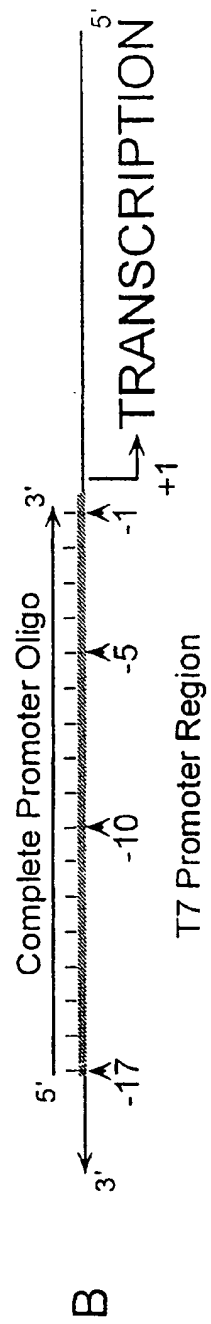
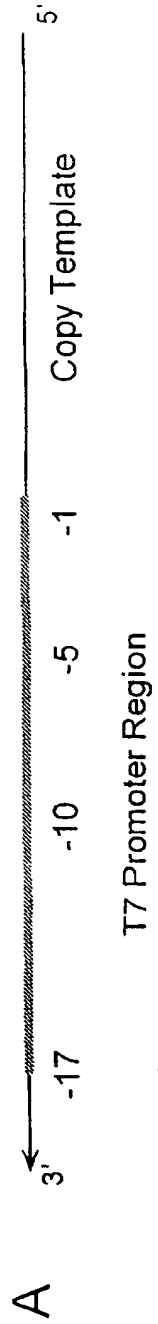


Fig. 85



Controls to test hicked promoters

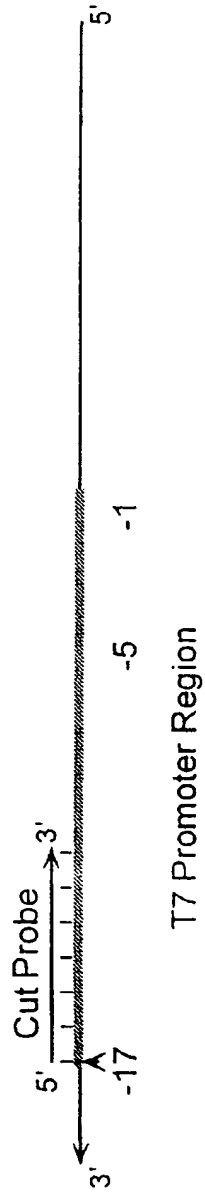


FIG. 86 A

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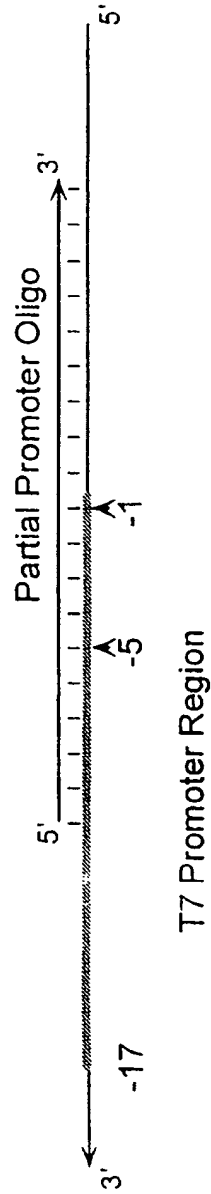


FIG. 86 B

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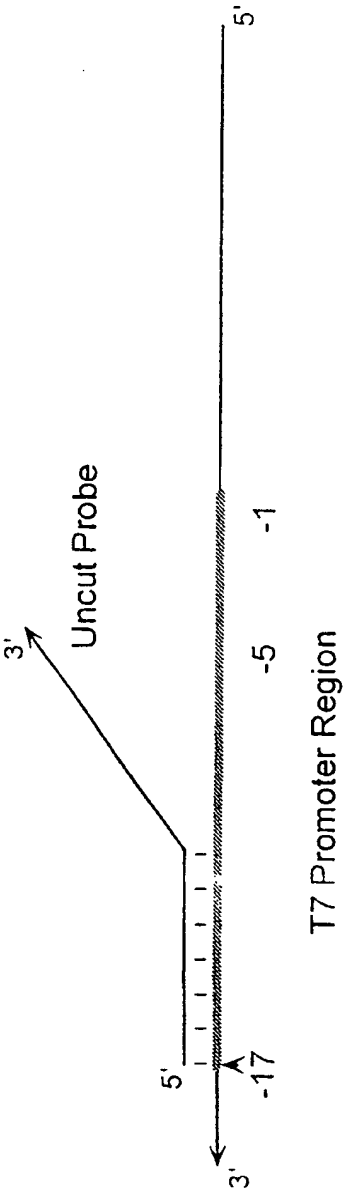


Fig. 86 C

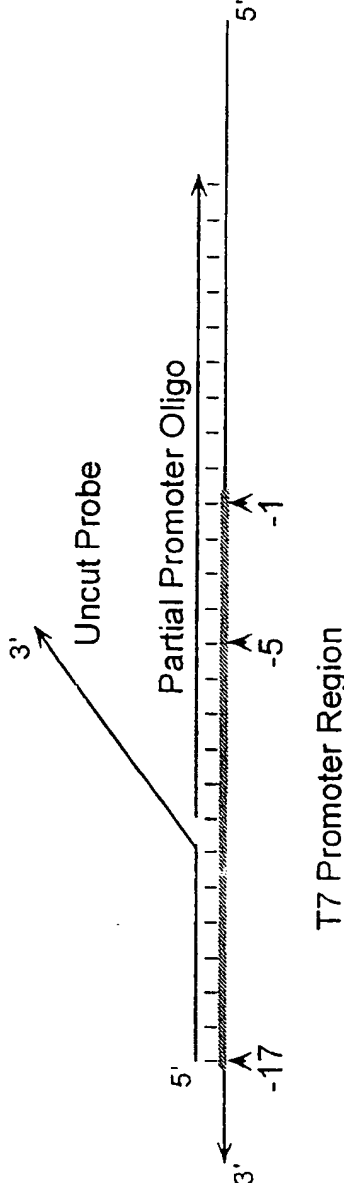
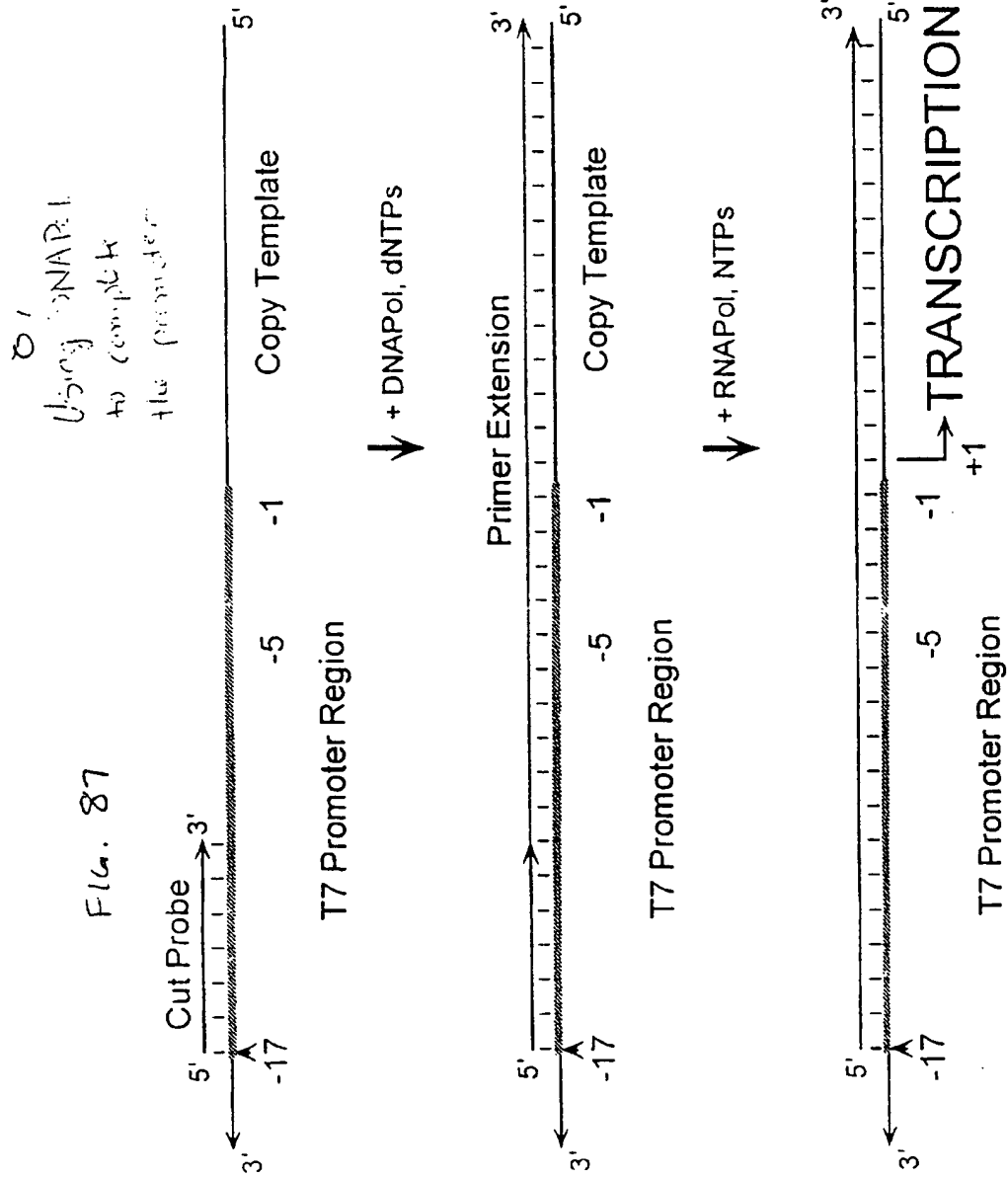


Fig. 86 D

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FIG. 87



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Nick position to allow
trans only w/cut probe

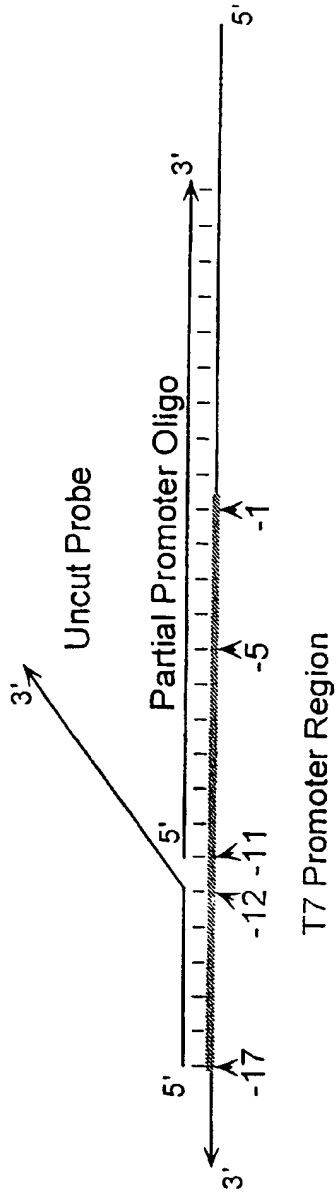


FIG. 88 A

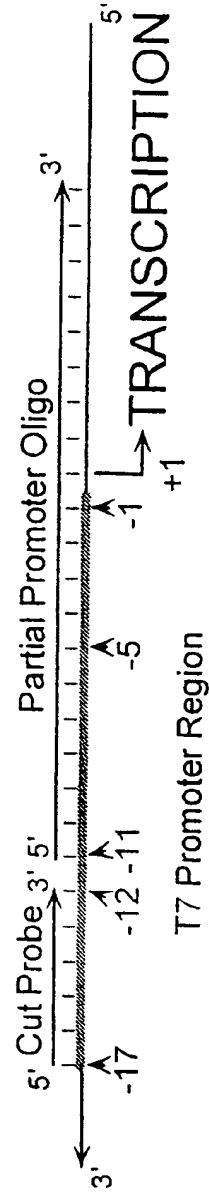


FIG. 88 B

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Fig. 89

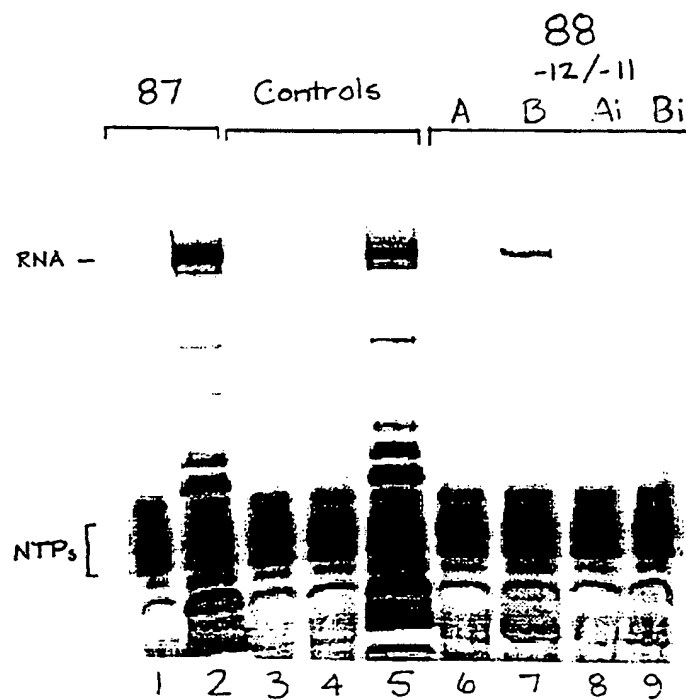
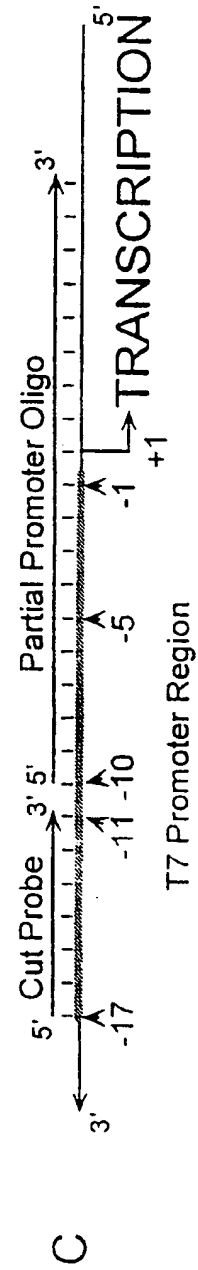
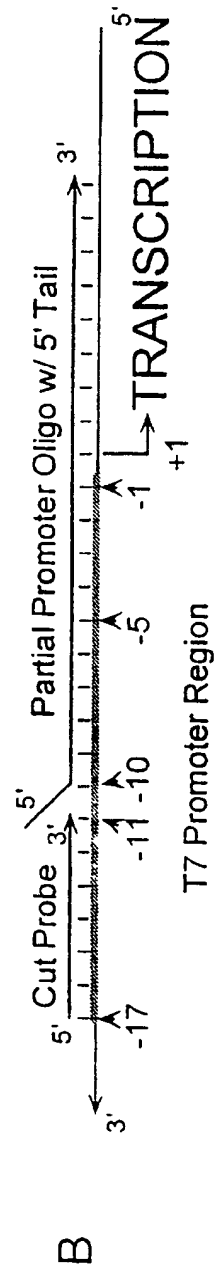
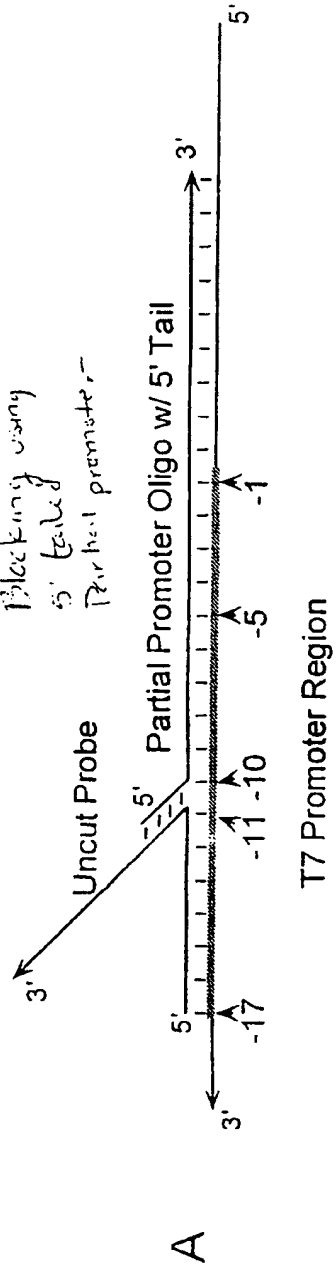


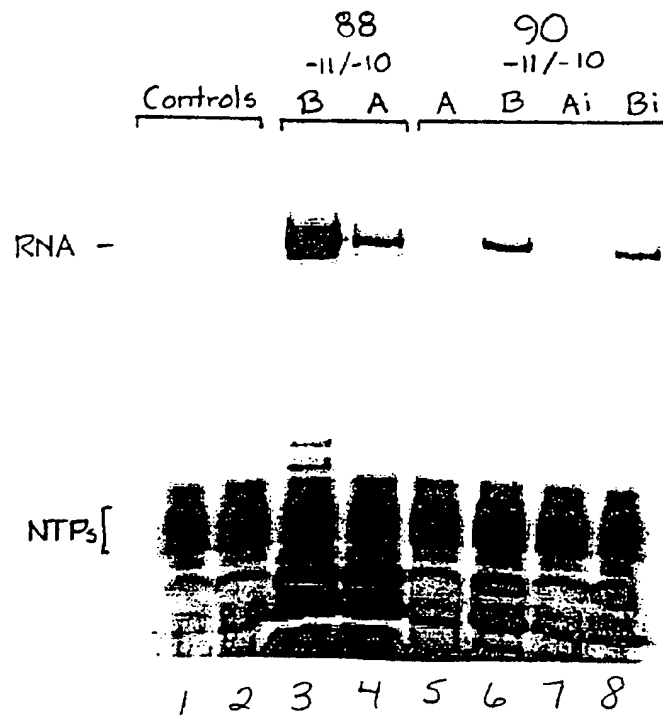
FIG 90

Blocking using
5' tailed
Partial promoter



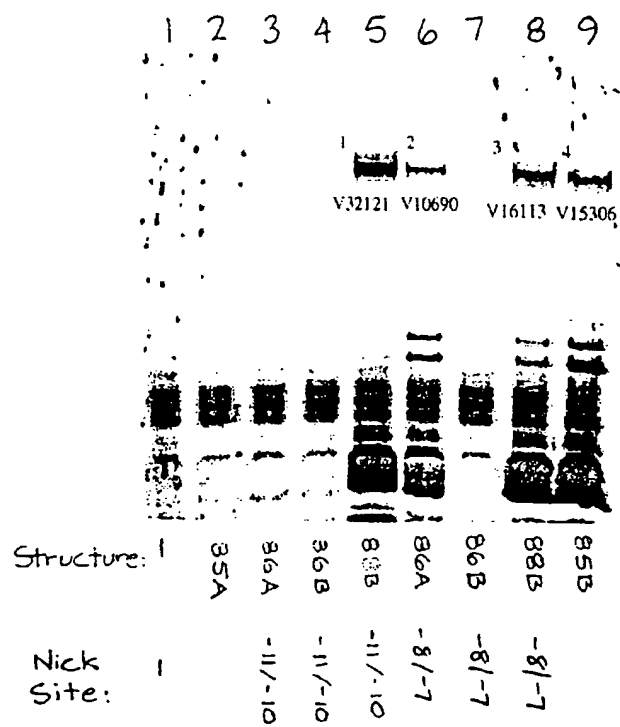
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Fig 91



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FIG. 92

Effect of
nick site

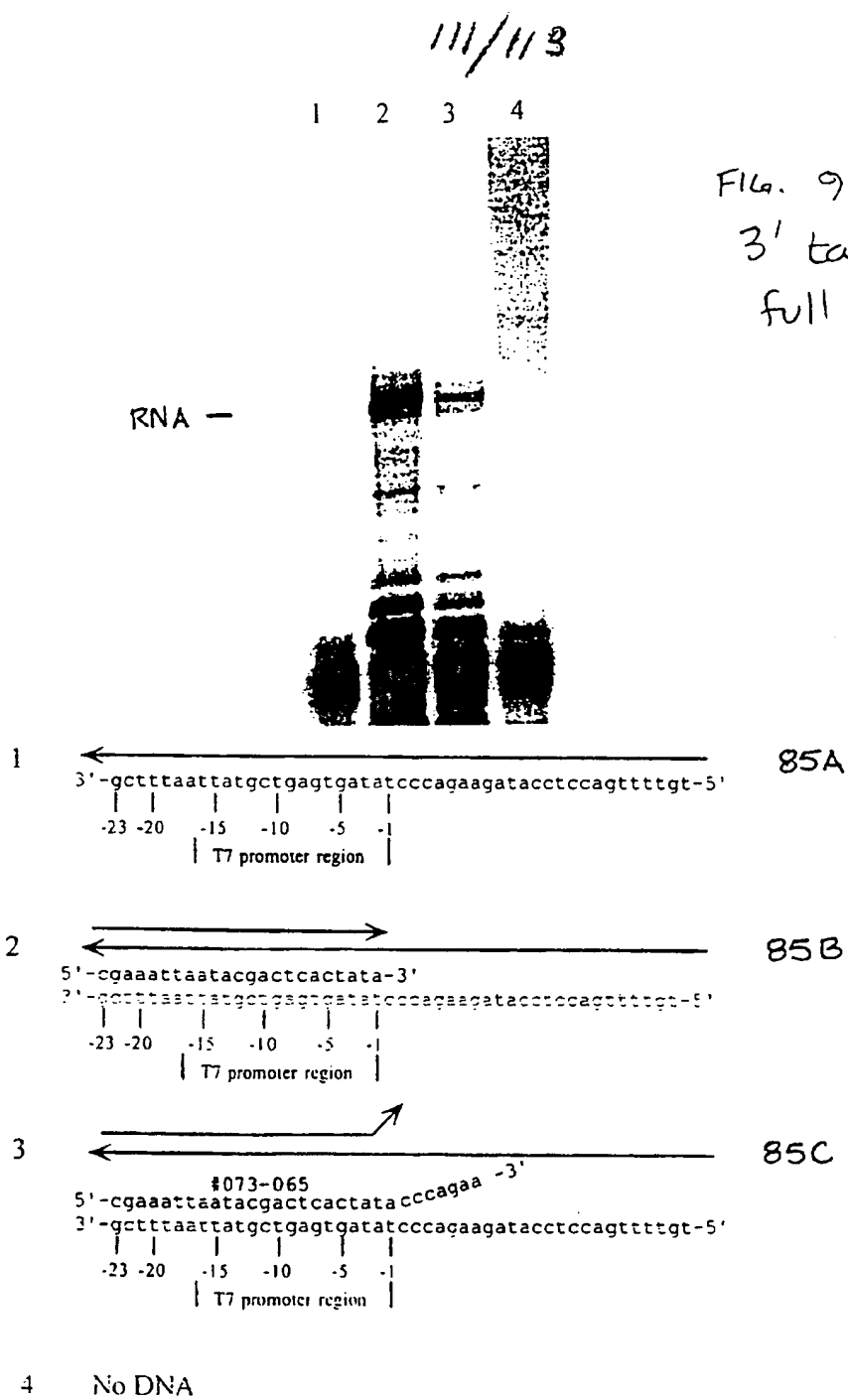
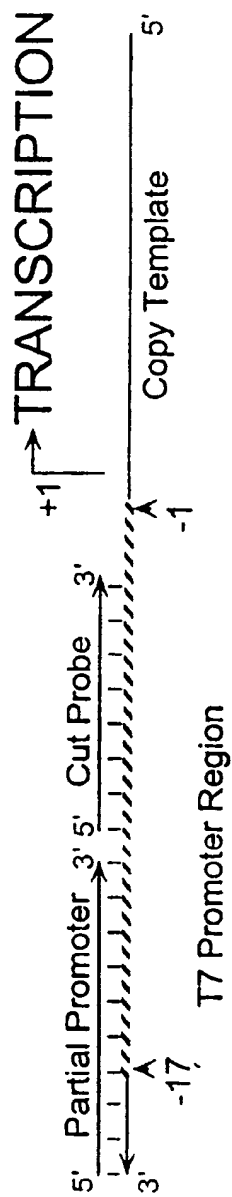


FIG. 93
3' tail on
full promoter

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Fig. 94



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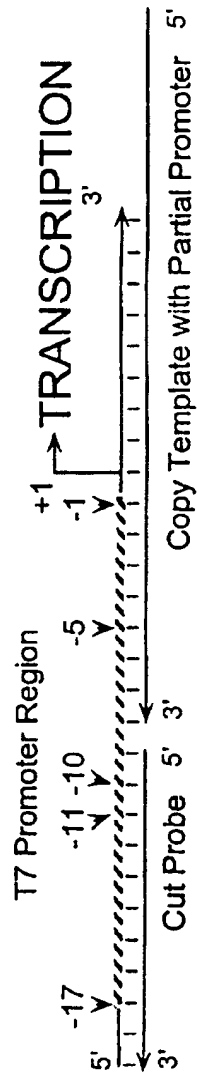


FIG. 95 A

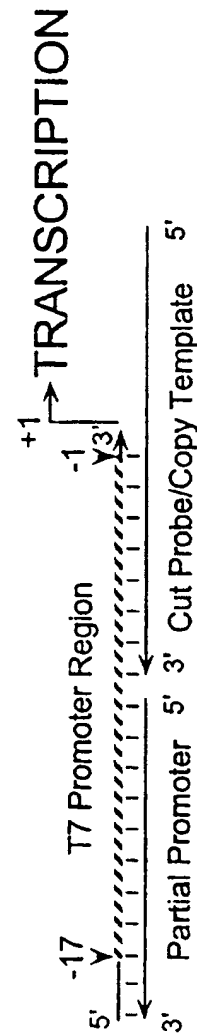


FIG. 95 B

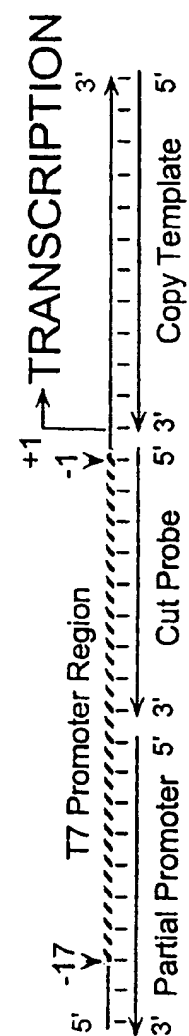


FIG. 95 C

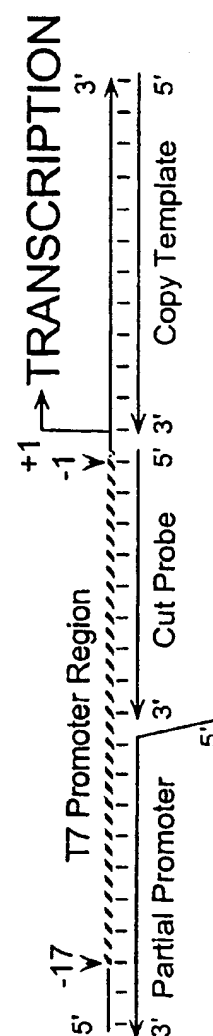


FIG. 95 D

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/01072

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : Please See Extra Sheet.

US CL : 435/6, 240.2, 320.1; 530/350; 536/23.1, 23.2

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/6, 240.2, 320.1; 530/350; 536/23.1, 23.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	HARRINGTON et al. Functional domains within FEN-1 and RAD2 define a family of structure-specific endonucleases: implications for nucleotide excision repair. Genes & Development. 01 June 1994. Volume 8, pages 1344-1355, especially pages 1346-1347 and Figure 1.	6-16
Y	EP 0411186 A1 (ABBOTT LABORATORIES) 06 February 1991 (06.02.91), see entire document, especially column 3, lines 25-53 and column 9, lines 23-47.	45-78
Y	US 5,210,015 A (GEFLAND et al) 11 May 1993 (11.05.93), see entire document, especially columns 13-15.	25-44

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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*E earlier document published on or after the international filing date	*Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
*L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*& document member of the same patent family
*O document referring to an oral disclosure, use, exhibition or other means	
*P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

03 APRIL 1997

Date of mailing of the international search report

05 JUN 1997

Name and mailing address of the ISA/US
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Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

DEBRA SHOEMAKER

Telephone No. (703) 608-0196

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/01072

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,422,253 A (DAHLBERG et al) 06 June 1995 (06.06.95), see entire document.	1-44 ----- 45-95
X,P --- Y,P	US 5,541,311 A (DAHLBERG et al) 30 July 1996 (30.07.97), see entire document.	1-44 ----- 45-95

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US97/01072

A. CLASSIFICATION OF SUBJECT MATTER:

IPC (6):

C07K 14/00; C07H 21/04; C12N 15/11, 15/63, 15/85, 15/86; C12Q 1/68

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

Searched inventors and keywords: charge balanced or neutral oligonucleotide, structure specific or fen endonuclease and detect target nucleic acid or polynucleotide or dna in APS, CAPLUS, MEDLINE, SCISEARCH, BIOSIS WPIDS and GENBANK